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An Analysis of Ground-Flight Loads Measured on the Instrumented B-727 N40

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16. Abstract

The Federal Aviation Administration Technical Center owns and operates an instrumented B-727 aircraft for in-house test and assessment of runway friction and to examine landing gear impact on runway surfaces. Numerous strain gages were installed on the landing gear. Prior analysis of the data was concerned primarily with supporting the FAA's airports research program. It was recognized that this data set also has application in correlating the aircraft internal gear loads to measured ground-flight loads for specific takeoff and landing conditions and runway operations.

This in-house research affords the National Aging Aircraft Research Program an opportunity to assess new data, independently obtained, which is both of high quality and having unusually high sampling rates to examine the landing gear loads for a limited number of takeoff, landing, and ground maneuvers.

Sixty sample-per-second time history traces were available for each of 72 events with the following breakdown:(1) Takeoff analysis, 22 events; (2) Landing analysis, 18 events; (3) Runway exit analysis, 9 events; (4) Braking analysis, 6 events; (5) S-turn analysis, 9 events; and (6) Minimum-radius turn analysis, 8 events.

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EXECUTIVE SUMMARY

The Federal Aviation Administration Technical Center owns and operates an instrumented B-727 aircraft for in-house test and assessment of runway friction and to examine landing gear impact on runway surfaces. Numerous strain gages were installed on the landing gear. Prior analysis of the data was concerned primarily with supporting the FAA's airports research program; however, it has been recognized that this data set also has application in correlating the aircraft gear loads to measured ground-flight loads for specific takeoff and landing conditions and runway operations. This in-house research affords the National Aging Aircraft Research Program (NAARP) an opportunity to assess new data, independently obtained, which is both of high quality and unusually high sampling rates to examine the landing gear loads for a limited number of common aircraft maneuvers. Sixty sample-per-second time history traces were available for each of 72 events with the following breakdown:(1) Takeoff analysis, 22 events; (2) Landing analysis, 18 events; (3) Runway exit analysis, 9 events; (4) Braking analysis, 6 events; (5) S-turn analysis, 9 events; and (6) Minimum-radius turn analysis, 8 events.

Multiple time trace data plots of all maneuvers illustrate variable relationships as expected. Pitch rate was calculated for all takeoffs that had available angle data. The average pitch rate was calculated to be 3.43 degrees per second, while the maximum was 4.63 degrees per second. Histograms were plotted and mean, median, and standard deviations were calculated for all takeoff and landing critical parameters although the small number of samples caused a large amount of uncertainty. Measured values were compared with calculated ones and had good agreement, although a great deal of scatter was illustrated for the measured and calculated braking drag shear. This is partially due to the large bias in the measured braking accelerations compared to the calculated accelerations. Measured accelerations agree well with measured forces. Relationships between braking acceleration and drag shear, lateral acceleration and side shear, and normal acceleration and vertical shear were determined for the braking, exiting, and landing tests respectively. A linear relationship exists between side shear and axle differential load.

1. INTRODUCTION.

1.1 Background.

The uses and applications of many of the older commercial aircraft operating today (i.e., DC9, B-727) have slowly evolved over the past 30 years since the conception of the design. Many common ground maneuvers such as aircraft braking and exiting are different due to changes in airport capacity or aircraft use. Most of the data available describing aircraft loads during takeoff, landing, and ground maneuvers is as much as 30 years old, where prior generation equipment was used acquiring data at possibly insufficient data rates. This study examines some recently obtained high quality, independent data with high sample rates, to measure and correlate landing gear internal and external loads experienced during takeoff, landing, and some selected abrupt ground maneuvers.

The data will provide an understanding of the relationships between the external conditions (i.e., runway exit speed) and the internal loads (e.g., individual main gear loads) which may be of value in understanding service problems on the older airframes and will assist in the development of the design loads and operating loads on new designs.

1.2 Scope.

Data reduction of extensive ground and flight tests in support of the FAA airport runway friction research was reconfigured to allow for the analysis of gear loads. All data were acquired from the flight test data acquisition system on the FAA Technical Center's research transport B-727 N40 and most data came from experiments performed to examine ground handling performance. Figure 1 gives a plan view of a B-727-100QC. The flight and ground tests in the subject study include several different maneuvers such as a takeoff or runway exit. Other data files that have been made available are from tests to evaluate runway friction, soft arrester system foam performance, and other runway parameters. Figure 2 is a photograph of the FAA Technical Center's B-727 N40 during taxi. Appendix A provides tables of all useful test data files available including parameters describing the test objectives and conditions. These parameters (i.e., gross weight, wind speed, and direction) are used for correlation of measured internal loads for individual flight tests.

The purpose of this study was to utilize existing high speed B-727 data to compile the flight acceleration, aircraft system, and force data for each maneuver into data files, and to analyze the flight information to provide a typical picture of each aircraft maneuver. Relationships describing takeoff, landing, exit, braking, S-turn, and minimum-radius turn aircraft maneuvers were examined. These relationships provide some directly measured internal loads information not available in previous research efforts.

2. DATA ACQUISITION AND REDUCTION.

2.1 Data Channels.

Since the focus of the testing was ground handling, most data channels consisted of landing gear information such as axle/strut forces, wheel braking forces, wheel sideslip angles, and wheel speeds. Other analog inputs consist of the standard control inputs and engine pressure ratios (EPRs), as well as cockpit and cg accelerations. Most digital inputs came from the air data computer (ADC) which contains the inertial navigation system's (INS) output as well as other digital flight parameters. These values are typically flight path angles, headings, and other data intrinsic to the aircraft's flight instrument presentation. Ground speed and distance were provided by a digital distance sensor which, by means of a focused light beam, provided a digital pulse every 2.5 mm of ground distance. A view of this device mounted on the front landing gear can be seen as figure 3.

Strain gages were installed on all of the landing gear axle assemblies. The main gear installation is illustrated in figure 4. This installation combination allows for the measurement of vertical shear, braking shear, and side shear. Although each wheel axle was instrumented separately, each landing gear assembly (left and right wheel axle) were calibrated together by attaching the entire landing gear to a load cell platform and incrementally lowering the aircraft onto the platform (see figure 5). Although this method gives an accurate calibration of the three basic force directions, it does not provide the individual axle force calibration or the cross-coupling of the strain gage outputs from axle to axle and gage to gage. Thus, the accuracy of axisymmetrical loads on the landing gear has not been determined. Appendix B describes the basic calibration procedure for the three landing gears.

2.2 Data Acquisition System and Data Reduction.

The data acquisition system installed on the B-727 is a Metraplex hybrid data acquisition system which has a series of digital cards to acquire analog and different forms of digital data and creates a pulse-code modulated (PCM) encoded bit stream as output (see figure 6). The B-727 data acquisition system has an Eidel PCM 760 decoding card to decode the PCM bit stream from the Metraplex system. The PCM decoding card utilizes two source files to decode the PCM bit stream and create a data "frame" which contains all data channels, time code, and other important frame information. The data frame is then saved as a binary sequential data file, along with an ASCII "playback" file which contains the time code information. The signal file and the format file are the two source files utilized by the EE315 software to make binary sequential data files from the encoded PCM data stream. It is important to note that not every test employed the same signal file, or even the same channels, since the EE315 software allows the option of saving some or all of the channels specified in the Metraplex data frame.

In order to obtain an ASCII data file with a valid time code and data columns from the Eidel binary sequential file system, a software package was developed to allow the user to convert specified data from the file. This software is also used to apply calibration factors and formulas, add or average columns, and filter the data by frequency. This program was written in QBasic and allows the user to obtain any data channels desired from the data frame for any specified time frame, as well as vary the output data rate. Because many data channels were redundant and unnecessary for this study, not all data channels were converted to ASCII for analysis. Appendix C gives a list of all data channels converted to ASCII with units and range. A listing of this program can be seen in appendix D.

2.3 Data Filtering.

As is customary with most analog force related instrumentation measurements, the data was filtered in two stages. All strain gage signals are first passed through a signal conditioner, which amplifies and then low-pass filters the data for antialiasing. Most other analog signals contain some internal amplification and filtering. The analog and digital signals are then sent to the data acquisition system and stored. When the binary sequential data is processed and made into ASCII files, a fourth-order Butterworth IIR digital filter is applied to reduce high frequency noise, and to antialias signals that are stored at a lower sample rate in the ASCII files than in the original binary files. The effect of the filter on ten seconds of data can be seen in figures 7 and 8.

3. ANALYSIS.

3.1 General Analysis Techniques.

To reduce the data, the raw 60 Hz data were digitally filtered at 5 Hz and decimated by 2 (every second point eliminated). The cutoff frequency (F_c) was chosen to allow for the lowest possible cutoff frequency that is significantly greater then the aircraft body natural frequency (3.5 Hz) and the data were decimated to allow for easier file management. This gives a reduced data rate of 30 Hz filtered at 5 Hz. The data were analyzed both in time history and for specific event values such as peak aircraft longitudinal acceleration which take place at or over some period of time.

For analysis in time, certain time trace data were correlated to verify the validity of the data and also to illustrate certain key parameter relationships. Correlation in time of two parameters was achieved by plotting each parameter on a separate axis for a selected time period. Relationships between the two parameters could then be observed and analyzed. When relating two parameters in time, they were related over a specific time period pertinent to the maneuver, and only data obtained during this specific time period were considered for correlation. All leading and lagging data points were "trimmed" to reduce data scatter. These special trimmed files also provided a basis for determining specific event values, which were often an average value over a small interval of time during the event.

For the analysis of specific event parameters, each aircraft maneuver specific event value was determined and tabulated. Each specific event parameter was chosen for its relevance to each maneuver (i.e., landing normal acceleration at touchdown). These values were tabulated for evaluation and possible correlation between tests, whereas each flight segment had a prime focus for analysis. Statistical analysis of these critical values was also performed for the takeoff and landing events, where a histogram of each specific event parameter was plotted and mean, median, and standard deviations were calculated for each histogram using CoStat, a commercial software package. Specific event parameters were also compared with calculated values to gage the accuracy of the data and to verify the means by which acceleration is translated to force. Specific event values were also correlated with each other to determine possible relationships, although correlation of these values was difficult due to the limited amount of test events for each maneuver. However, even with this limited data, some significant relationships were determined.

3.2 Takeoff Data Analysis.

The primary focus of the takeoff data analysis was on takeoff velocity and rotation data. Some takeoff tests did not have aircraft flight path angles available for analysis, thus reducing the number of flight events available for analysis. The key parameters tabulated for each takeoff test other than the basic test information were peak longitudinal acceleration (N_x), maximum ground speed (V_{max}), runway distance used (ΔD), time to liftoff (t_{lo}), maximum pitch angle (θ_{max}), and maximum pitch rate (PR_{max}). The maximum takeoff velocity adjusted for wind speed was also tabulated. These parameters are illustrated in figure 9. The peak longitudinal acceleration was approximated by drawing a best fit curve to the acceleration time trace, and then determining the peak value. The ground speed and distance sensor was located on the nose gear (see section 2.2) and these values had to be estimated after nose gear liftoff. Maximum ground speed was assumed to be the ground speed at the start of rotation, and the runway distance utilized after rotation started was approximated by dividing the maximum ground speed by the time remaining until main gear liftoff. Histograms of each critical parameter were calculated and plotted for all tests and the mean value, median value, and standard deviation were calculated. Also, takeoff speed was correlated with takeoff distance and time to liftoff to determine the relationship between these takeoff parameters.

3.3 Landing Data Analysis.

The primary focus of the landing data analysis was data available on vertical cg acceleration and peak axle vertical shear at aircraft touchdown. The key parameters tabulated for each landing other than the basic flight information were peak vertical acceleration (N_z), nose gear touch down ground speed (V_{td}), touchdown pitch angle (θ_{td}), and peak main landing gear vertical shear (VS_{MLG}). The touchdown ground speed adjusted for wind velocity was also tabulated. These parameters are illustrated in figure 10. Histograms were calculated and plotted for each critical parameter and the mean value, median value, and standard deviation were calculated. In an attempt to gage the accuracy of the data, landing vertical shear was calculated using the following equation and compared to the measured vertical shear.

$$VS_{MLG} = N_z \; W_{AC} \tag{1}$$

Where W_{AC} is the aircraft landing weight, vertical shear and normal acceleration are single peak values. Peak landing gear vertical shear was correlated with normal acceleration and also pitch angle at touchdown was correlated with aircraft weight in an attempt to determine the relationship between these landing parameters.

3.4 Runway Exit Data Analysis.

The main focus of the exit analysis was to obtain the relationship between landing gear side force and lateral acceleration, as it relates to different exit speeds on a standard runway exit ramp. Measured side shear was correlated in time with measured lateral acceleration for a 40-, 50-, and 60-knot exit to illustrate the relationship between the two parameters and verify the quality of the measurements. As stated in section 3.1, only the period of time during which the aircraft was actually exiting the runway was analyzed. Time averages of some critical values were utilized to allow for correlation of tabulated critical parameters. Key parameters tabulated were exit time interval (Δt), exit distance interval (ΔD), average ground speed (V_{ave}), average lateral acceleration (N_y), average main landing [illegible] (SS_{MLG}), and peak main landing gear vertical shear (VS_{MLG}). These values [illegible]. To verify measured average lateral acceleration and average side shear, [illegible] calculated utilizing other measured values. To calculate average acceleration, the average turn radius was first calculated.

$$\bar{r} = \frac{\Delta D}{\theta} \tag{2}$$

In the above equation θ is the angle representing the change in path of [illegible] and the over bar represents a time averaged value. Assuming the lateral [illegible] equal to the centrifugal radial force, the following equation was used to calculate average lateral acceleration.

$$\bar{N}_y = \frac{V_{gnd}^2}{\bar{r}} \tag{3}$$

Again, the over bar represents a time averaged value. Average side shear can be calculated using average measured lateral acceleration (N_y) and aircraft weight (W_{AC}).

$$\bar{SS}_{MLG} = \bar{N}_y \, W_{AC} \tag{4}$$

These simple calculations can help validate the accuracy of some measured parameters. To compare side force with lateral acceleration in time, side force coefficient was calculated using the following formula.

$$C_{ss} = \frac{SS_{TOT}}{W_{AC}} \tag{5}$$

In the above equation C_{SS} is a local time value at the local total side shear SS_{TOT}. Note that the above equation represents the reverse calculation of equation (4). Also, lateral acceleration was correlated with exit speed and landing gear side force. Side shear was also correlated with exit speed to illustrate this relationship. The aircraft wheel brakes were not applied during the exit tests while the aircraft was traveling through the turn. All the data presented for the exit tests were measured with the wheels freely rolling. The optional nose wheel brakes were disabled.

3.5 Braking Data Analysis.

Braking data were analyzed in an attempt to obtain a relationship between braking acceleration and axle drag shear. Measured drag shear was correlated in time with measured longitudinal acceleration for several braking events of different intensities to illustrate the relationship between the two parameters and to verify the quality of the measurements. Only the portion of each braking test which involved actual braking was analyzed. The key parameters utilized for each of these braking events included change in speed (ΔV), time to change speed (Δt), braking distance (ΔD), average braking acceleration (N_x), average total drag shear (DS_{MLG}), and maximum braking pressure (P_{brk}). Also, the initial ground speed at the start of braking was recorded (V_{strt}). These values are illustrated in figure 12. To verify measured average acceleration and average drag shear, values were calculated utilizing other measured values. Average acceleration can be calculated by using change in velocity (ΔV) and time (Δt) using the following formula.

$$\bar{N}_x = -\frac{\Delta V}{\Delta t} \tag{6}$$

Average drag shear can be calculated using average measured acceleration (N_x) and aircraft weight (W_{AC}).

$$\bar{DS}_{MLG} = \bar{N}_x \, W_{AC} \tag{7}$$

The average acceleration tabulated was correlated with the average drag force tabulated to obtain a relationship between the two parameters. All braking tests utilized were performed on dry pavement except TST71001. Note, as for the exit tests, the nose wheel brakes were disabled.

3.6 S-Turn Data Analysis.

The primary focus of S-turn data analysis was to examine the vertical shear axle differential loads experienced during lateral acceleration due to the aircraft's lateral movement. Axle differential load is defined as the difference between the left axle vertical shear and the right axle vertical shear for a left turn. Measured side shear was correlated in time with measured lateral acceleration for a 40-, 60-, and 80-knot S-turn to illustrate the relationship between the two parameters and verify the quality of the measurements. Also to verify the validity of the data, the side force coefficient was plotted with lateral acceleration in time. As stated in section 3.1, only the period of time during which the aircraft was actually executing an S-turn was analyzed. Time averages of some critical values were utilized to allow for correlation of tabulated critical parameters. Key parameters tabulated were S-turn start speed (V_{strt}), time interval (Δt), average lateral acceleration (N_y), average landing gear side shear for each main landing gear (SS_{LMG}, SS_{RMG}), and average landing gear vertical axle differential load (ADL_{RMG}, ADL_{LMG}) for each main landing gear. The maximum main landing gear vertical axle differential load (ADL_{MLG}) was also tabulated. These parameters are illustrated in figure 13. To verify measured average side shear, values were calculated using measured average lateral acceleration and aircraft weight.

$$\bar{SS}_{MLG} = \bar{N}_y \, W_{AC}$$

In this equation SS_{MLG} is the total side shear on both landing gear. Side shear was correlated with axle differential load and also with lateral acceleration in an attempt to determine the relationship between these parameters. Braking was not used during the S-Turn tests and the optional nose wheel brakes were disabled for the testing.

3.7 Minimum-Radius Turn Data Analysis.

The primary focus of minimum-radius turn data analysis was the examination of the nose gear side shear and vertical shear axle differential loads experienced during the maneuver. Measured side shear on the nose gear was plotted in time with measured nose gear axle differential load for a clockwise (CW) and counter clock wise (CCW) minimum-radius turn to illustrate the relationship between the two parameters. An arbitrary ten-second period of time at which the aircraft was actually executing the turn was analyzed when considering time correlation and averages. Key parameters tabulated were minimum-radius turn time interval (Δt), average nose gear tangential velocity (V_{tan}), average nose gear side shear (SS_{NG}), and average nose gear vertical axle differential load (ADL_{NG}). The maximum nose gear vertical axle differential load (ADL_{NG}) was also tabulated. These parameters are illustrated in figure 14. Nose gear side shear was correlated with axle differential load in an attempt to determine the relationship between these parameters. Braking was not used during the minimum radius turn tests and the optional nose wheel brakes were disabled for the testing.

4. RESULTS.

4.1 Takeoffs.

Figures 15 and 16 illustrate aircraft acceleration, ground speed, and aircraft angle data for two typical takeoffs of the instrumented B-727 N40. Note the peak longitudinal acceleration occurred early during the takeoff run time trace. The start of rotation is illustrated by the ground speed going to zero at approximately the same time the pitch angle reaches zero. Roll angle changes very little during the takeoff run. Liftoff is signified by a drastic decrease in noise on the normal acceleration data trace. Pitch data for each of the illustrated aircraft tests are given in figures 17a and 17b. Maximum pitch rate during TST63006 (2.57 deg/s) was much lower than in TST11408 (4.17 deg/s).

Table 1 contains the critical takeoff parameters discussed in section 3.2. The cells marked with an "X" indicate information that was not available for one or more reasons. The first four columns are information relative to the flight test itself (aircraft weight, wind speed, etc.), while the other seven columns represent the critical parameters.

To determine if the critical parameters collected are a good measure of expected values for an aircraft of similar or same type, a histogram of each critical parameter was plotted to determine if the scatter in the data are indeed a random deviation from an average value. Figures 18 through 24 illustrate histograms of the critical takeoff parameters, with each histogram displaying the sample size, mean, median, and standard deviation of the data field. Most histograms have a median value close to the mean value, which illustrates good symmetry.

It would be desirable if the takeoff distance could be related to takeoff velocity and aircraft weight. Figure 25 gives a correlation plot of takeoff distance versus takeoff speed to illustrate a potential relationship. Although some data scatter exists, a linear relationship can be observed. Figure 26 gives a correlation plot of takeoff distance versus aircraft weight. The plot illustrates a large amount of data scatter.

4.2 Landings.

Figure 27 and 28 illustrate aircraft accelerations, landing gear vertical shear, and pitch angle data for two typical landings of the instrumented B-727 N40. Note the maximum normal acceleration did not always occur at touchdown, although it does for the two given landings and it is this touchdown normal acceleration which is the focus of the landing acceleration data. Touchdown has occurred when there exists a sudden increase in the vertical shear and the drastic increase in noise on the normal and longitudinal acceleration data trace. The landing pitch angle time trace is different for each individual landing, however the maximum pitch angle at touchdown is a fairly consistent value.

Table 2 contains the critical landing parameters discussed in section 3.3. The cells marked with an "X" indicate information that was not available for one or more of the reasons discussed in section 2.3. The first four columns are information relative to the flight test itself (aircraft weight, wind speed, etc.), while the other five columns represent the measured landing parameters.

As discussed in section 3.2, the peak vertical shear values measured at touchdown were compared to values calculated with acceleration and aircraft weight. This comparison is shown graphically as figure 29. Although agreement is not always good, many calculated values have less than 10 percent error from the measured. Acceleration and weight consequently are not the only two parameters which correlate with shear. There is not sufficient data in this study to perform a more in depth analysis, however given that peak vertical shear is a function of N_z and W_{ac} (Equation 4), vertical shear is predicted with a correlation coefficient of 0.798. This is likely explained due to ground friction forces and airplane dynamics affecting the aircraft cg accelerations.

To determine if the critical parameters collected are a good measure of expected values for an aircraft of similar or same type, a histogram of each critical parameter was plotted to determine if the scatter in the data is indeed random deviation from an average value. Figures 30 through 34 illustrate histograms of the critical landing parameters, with each histogram displaying the data fields size, mean, median, and standard deviation. Most median values are close to the mean, indicating symmetry.

It would be desirable to correlate touchdown vertical shear with normal acceleration experienced. Figure 35 gives a correlation plot of touchdown vertical shear versus touchdown normal acceleration with a correlation coefficient of 0.784. Although a relationship is evident, the problems with relating these two parameters discussed in the previous paragraph are illustrated by the data scatter. Figure 36 gives a correlation plot of touchdown pitch angle versus aircraft weight with a correlation coefficient of 0.512. Again, a relationship is evident but the low data confidence is illustrated by the large amount of data scatter causing a poor correlation.

<u>4.3 Runway Exits.</u>

Figures 37, 38, and 39 illustrate aircraft acceleration, landing gear vertical shear, and landing gear side shear for three separate runway exits at 40, 50, and 60 knots respectively. Viewing the succession of graphs illustrates the increase in lateral acceleration and axle shears as the exit speed increases. To determine if side shear magnitude and time behavior are accurate and reasonable, the side force coefficient was calculated and plotted along side lateral acceleration. Figure 40 gives the side force coefficient comparison which illustrates a tendency for the side force coefficient to be high, particularly at heavy side loading. This could be due to torque on the strut amplifying the side force, or to absorption of force by the aircraft suspension, giving less acceleration at the aircraft cg. A biased high calibration factor would also cause this phenomena. Landing gear side shear was plotted against lateral acceleration in time for the three exits illustrated, and presented as figure 41. As mentioned in section 3.4 only the time values during the aircraft exit were used in making the graph. Although the plot exhibits modest scatter, a good linear relationship is observed. The weight of the aircraft varied from 134,726 pounds to 132,326 pounds, accounting for some of the plot scatter, while the least scatter is observed at high acceleration values with the side shear peaking at about 32,000 pounds.

Table 3 contains the critical exit parameters discussed in section 3.4. The first two columns are information relative to the flight test itself, while the other five columns represent the critical parameters. As discussed in section 3.4 most of these values are time averages, allowing for easy verification of the validity of the data. To help verify measured lateral accelerations, a graph comparing measured and calculated lateral accelerations is contained in figure 42. Note the excellent agreement in the regular and high speed exits. A comparison of measured and calculated side shear is plotted in figure 43. Again excellent agreement can be observed between measured and calculated values, illustrating the high quality of the data.

Figure 44 is a correlation plot of average exit speed versus average lateral acceleration tabulated in the critical value tables. The linear relationship observed illustrates the consistency of lateral accelerations observed on any given exit. To determine how side shear relates to lateral acceleration, a correlation plot of the two parameters was plotted as figure 45. Similar good linearity is observed as is expected. The lateral acceleration critical parameter is an average based on the aircraft velocity during the exit, which is not subject to the ground roughness error seen in peak acceleration data. Figure 46 is a cross correlation of the previous two figures giving the relationship between average measured side shear and exit speed.

4.4 Braking.

Figures 47, 48, and 49 illustrate aircraft acceleration, ground speed, and landing gear drag shear for three separate braking tests with heavy, normal, and light braking respectively. The heavy braking test was run with maximum braking effort applied by the pilot, and the anti-skid system was in operation during the test (a Mark II Hydro-Aire antiskid system was installed on the test aircraft). Viewing the succession of graphs illustrates the decrease in acceleration and axle drag shears as the braking intensity decreases. To determine the drag shear loading behavior of the landing gear, drag shear was plotted against longitudinal acceleration for the three braking tests illustrated in figure 50. As mentioned in section 3.5 only the values during which the aircraft was braking were used. The data exhibits a significant scatter, as well as displaying different data grouping slopes. A possible explanation for the different slope of the heavy breaking data may be dynamic effects due to the antiskid device used in the B-727 braking system.

Table 4 contains the critical braking parameters discussed in section 3.5. The first two columns are information relative to the flight test itself, while the other seven columns represent the critical parameters. As discussed in section 3.5 most of these values are time averages, allowing for easy verification of the validity of the data. To help verify measured longitudinal accelerations, a graph comparing measured and calculated longitudinal accelerations is contained in figure 51. The calculated values are consistently biased high as compared to the measured values. A comparison of measured and calculated drag shear is plotted as figure 52. This plot exhibits normal scatter and is not biased towards either calculated or measured data.

Figure 53 is a correlation plot of average longitudinal acceleration versus the average measured drag shear. The poor correlation observed is probably a reflection of the inconsistencies observed in figure 50 discussed in the first paragraph in this section.

4.5 S-Turns.

Figures 54, 55, and 56 illustrate aircraft acceleration, ground speed, and landing gear drag shear for three separate S-turns of 80, 60, and 40 knots respectively. Although the slower speed turns reflect the longer time needed to travel the same distance at a lower velocity, the acceleration, vertical shears, and side shears appear about the same. This is most likely due to pilot input based on his understanding of the capability of the aircraft. To determine if side shear magnitude and time behavior are accurate and reasonable, side force coefficient was calculated and plotted along side lateral acceleration. Figure 57 illustrates the side force coefficient comparison which illustrated a tendency for the side force coefficient to be high, particularly at heavy side loading. This could be due to torque on the strut amplifying the side force, or to absorption of force by the aircraft suspension, giving less acceleration at the aircraft cg. A biased high calibration factor would also cause this phenomena. Figures 58, 59, and 60 are graphs of side shear and axle differential load plotted in time. With the exception of the left main gear of TST63008, side shear tends to relate 1:1 with axle differential load. A basic force analysis of a landing gear under lateral acceleration tends to agree with this result. Appendix E gives a loading diagram and analysis which illustrates that the relationship between side shear and axle differential load is based on the ratio of twice the loaded tire radius to the lateral patch distance, which is approximately 1.2. To determine the side shear loading behavior of the landing gear, side shear was plotted in time against lateral acceleration for the three S-turn tests illustrated in figure 61. As mentioned in section 3.1 only a small portion of the data obtained during the time the aircraft was executing a turn were used. The data exhibits an excellent linear relationship. Also, side shear was plotted in time against axle differential load and can be seen as figure 62. This graph also displays little scatter and a good linear relationship, although distinct "runners" of data protrude vertically from the data scatter, illustrating that another mechanism may cause changes in axle load differential while side shear remains constant.

Table 5 contains the critical S-turn parameters discussed in section 3.6. The first two columns are information relative to the flight test itself, while the other six columns represent the critical parameters. As discussed in section 3.6 most of these values are time averaged, allowing for easy verification of the validity of the data. To help verify measured data, a graph comparing measured and calculated side shear is contained in figure 63. The measured values are consistently biased high as compared to the values calculated with measured acceleration. This agrees with figure 57, which also illustrates a high bias toward the measured values.

Figure 64 is a correlation plot of average lateral acceleration versus the average measured side shear. These short time average values illustrate a good linear relation. Figure 65 is a correlation plot of average measured side shear and average measured axle differential load. Again these values relate well linearly.

4.6 Minimum-Radius Turns.

Figures 66 and 67 illustrate nose gear ground speed, nose gear vertical shears, and nose gear side shear. The trend of the side shear traces is for the side shear to be approximately zero when the aircraft is stationary and to increase to a value greater than one half the vertical shear force as the aircraft begins to move. The increase occurs over a short distance, when speed is low and remains fairly constant throughout the test. The difference between the left and right vertical shears shows the same trend, indicating that the primary cause of the differential vertical shears is rotation of the gear due to the side shear.

Video tape of the nose gear taken during the minimum-radius turns clearly shows, from the deformation of the tires, the presence of significant side shears and significant differential vertical loads, confirming the validity of the data in figures 66 and 67. Figure 68 is a single frame taken from the video tape and shows the nose gear traveling toward the camera.

Since the magnitude of the side shears shows little variation with speed once the aircraft is moving, it appears that the nose gear tire side forces are generated to resist the moment about the cg from side forces and moments at the main gear generated due to scrubbing and not to resist the centrifugal force at the cg. In this connection it should be noted that the speed traces shown in figures 66 and 67 are for the speed of the nose gear measured perpendicular to the nose gear axle. Speed at the cg was not measured, but from the ratio of cg and nose gear distances to the center of turn, it would be approximately one fourth the speed of the nose gear. At the maximum nose gear speed shown in the traces of 12 mph, a maximum lateral acceleration at the cg of approximately 1.6 ft/s^2 (0.05 g) is obtained. That there was significant scrubbing at the main gear wheels on the inside of the turn was shown by dark circular rubber tracks deposited on the pavement by the tires (see figure 69). The radius of the tire tracks showed that the center of the turn was about 3.5 feet outside the center of the main gear on the inside of the turn, giving a turn radius to the cg of approximately 13 feet.

Figure 70a and 70b illustrate nose gear side shear as compared to nose gear vertical axle differential load in time. Although there are discrepancies in both tests between the side shear and axle differential load, these can be generally associated with changes in speed. In test34 differential load and side shear agree very well during the first 45 seconds of the test when the nose wheel speed is increasing. Figure 71 is a correlation in time of nose gear side shear and axle differential load for both tests discussed above for an arbitrary 10-second time interval. Although the data from each test correspond very well, different characteristics are shown for clockwise and counter-clockwise turns.

Table 6 contains the critical minimum-radius turn parameters discussed in section 3.7. The first three columns are information relative to the flight test itself, while the other five columns represent the critical parameters. As discussed in section 3.7 most of these values are time averages, made over an arbitrary 10-second period during the turn, allowing for easy verification of the validity of the data.

Figure 72 illustrates a correlation of nose gear average side shear and average axle differential load. This graph illustrates two distinct groupings for the clockwise and the counter-clockwise turns which agree with figure 71. The cause of this behavior has not been determined.

5. CONCLUSIONS AND RECOMMENDATIONS.

From this study of flight-ground loads measured on the B-727 N40, the following conclusions can be drawn.

- Takeoff data had measured accelerations consistent with known reality and calculated maximum pitch rate had an average of 3.49 deg/s for the examined takeoffs with the maximum pitch rate observed being 4.17 deg/s. Although histograms were poor, mean values were consistent with median values. Most attempts at correlating specific event values illustrated a linear relationship, although correlation plots exhibit a great deal of scatter.

- Landing data were consistent with known reality and measured specific event values for vertical shear were consistent with measured vertical acceleration values. Although histograms were poor, mean values were consistent with determined median values. Specific event vertical shear values correlated fairly well with vertical acceleration and aircraft weight, but touchdown pitch angle correlated poorly.

- Runway exit time trace data illustrated the expected force-acceleration relationships, and measured side shear correlated very well with measured accelerations. Measured specific event values were consistent with calculated values and a direct relationship was established between exit speed and measured lateral accelerations. Side Shear force correlates well with exit speed and lateral acceleration.

- Aircraft braking time trace data illustrated the expected force-acceleration relationships, and measured drag shear correlated well with measured longitudinal accelerations with different relationships being observed for the different levels of braking. Measured specific event values were consistent with calculated values, with the measured accelerations being consistently higher than the calculated. Attempts to correlate drag force with longitudinal acceleration were difficult due to a small number of tests.

- S-turn time trace data were consistent with known reality, and measured lateral acceleration agreed well with measured side shear. Main landing gear side shear and axle differential load illustrate a distinct relationship which relates linearly in time. Specific event values for lateral acceleration, main landing gear side shear, and axle differential load all correlate well, illustrating their interwoven relationship.

- Minimum-radius turn time trace data was consistent with known reality, and measured nose gear side shear related well with measured nose gear axle differential load, although it is unclear how they relate in time. Specific event values for nose gear side shear and axle differential load agree poorly.

Additional takeoff and landing test events would be useful in obtaining better histograms, and therefore more accurate statistical information. Similarly, more runway exit data with many different exit velocities would be useful to allow for more complete correlation plots between landing gear side shear, lateral acceleration, and exit velocity. More consistent braking data would be useful in more accurately predicting drag shear. Multiple braking runs with and without the antiskid device in use could also help determine why different braking slopes give different slope scatter patterns on a correlation plot of longitudinal acceleration versus drag force. Although an obvious relationship between side shear and axle differential load exists, a recalibration of the B-727 landing gear would be needed to obtain the definitive relationship.

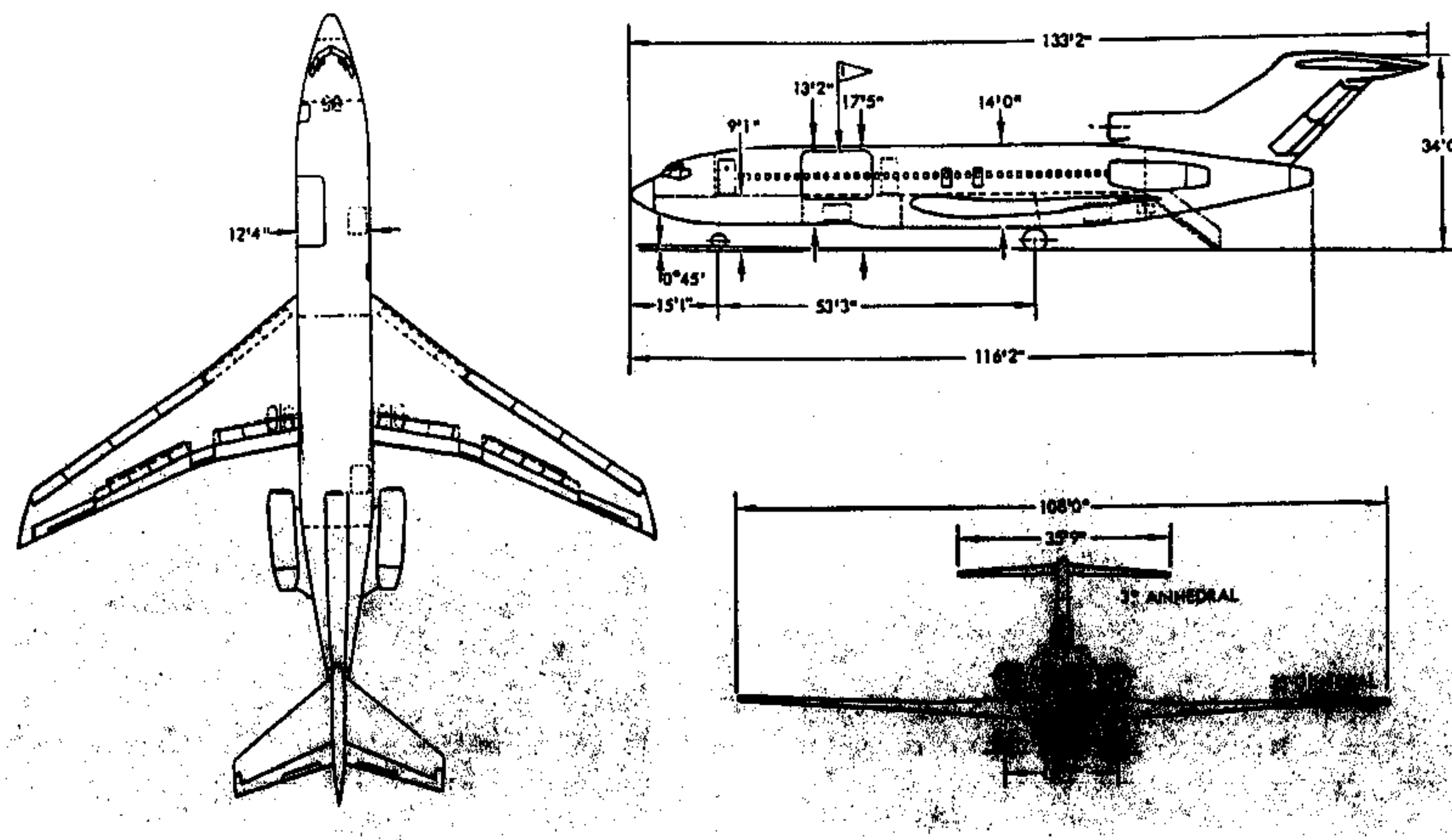


FIGURE 1. DIAGRAM OF B-727 ILLUSTRATING GEOMETRY AND SIGNIFICANT DISTANCES

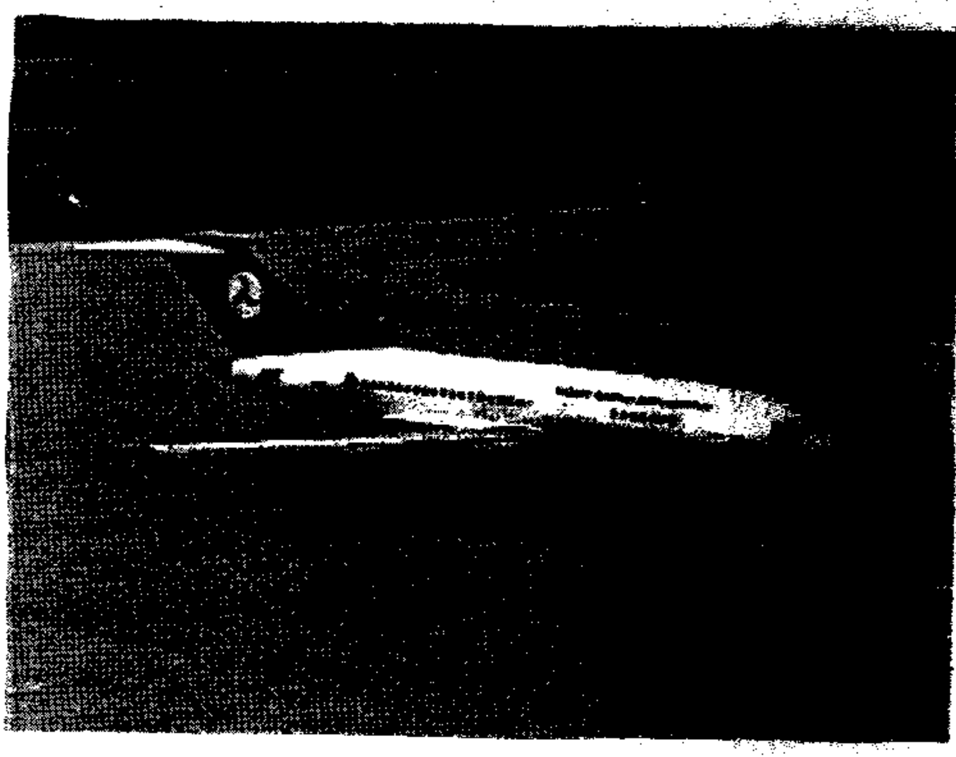


FIGURE 2. PHOTO OF THE B-727 N40 TAXIING TO PERFORM A MANEUVER

FIGURE 3. PHOTO OF DISTANCE SENSOR MOUNTED ON THE NOSE GEAR OF THE B-727 N40

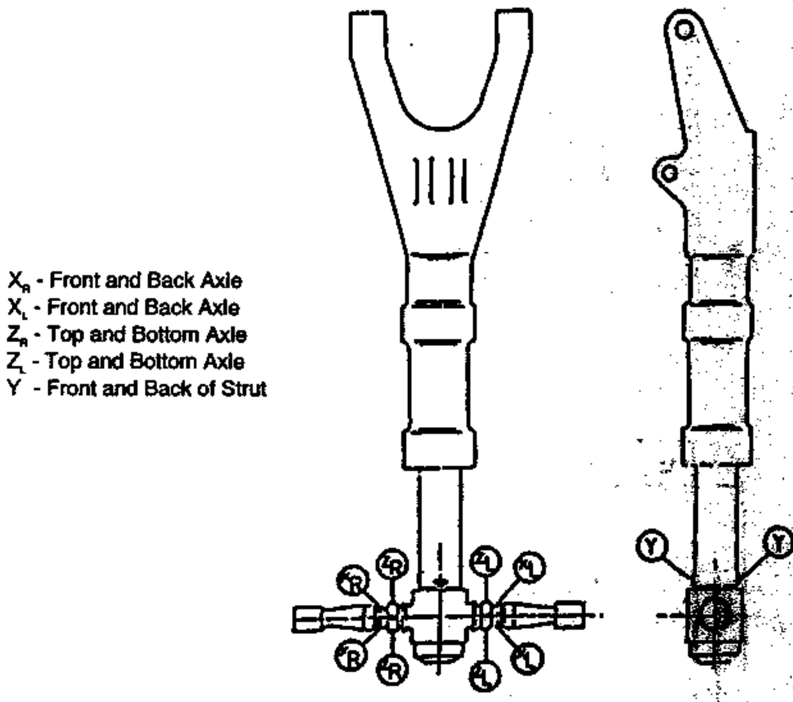


FIGURE 4. ILLUSTRATION OF STRAIN GAGE LOCATIONS ON THE B-727 N40 LANDING GEAR

FIGURE 5. PHOTO OF LANDING GEAR CALIBRATION ILLUSTRATING THE USE OF THE LOAD CELL PLATFORM

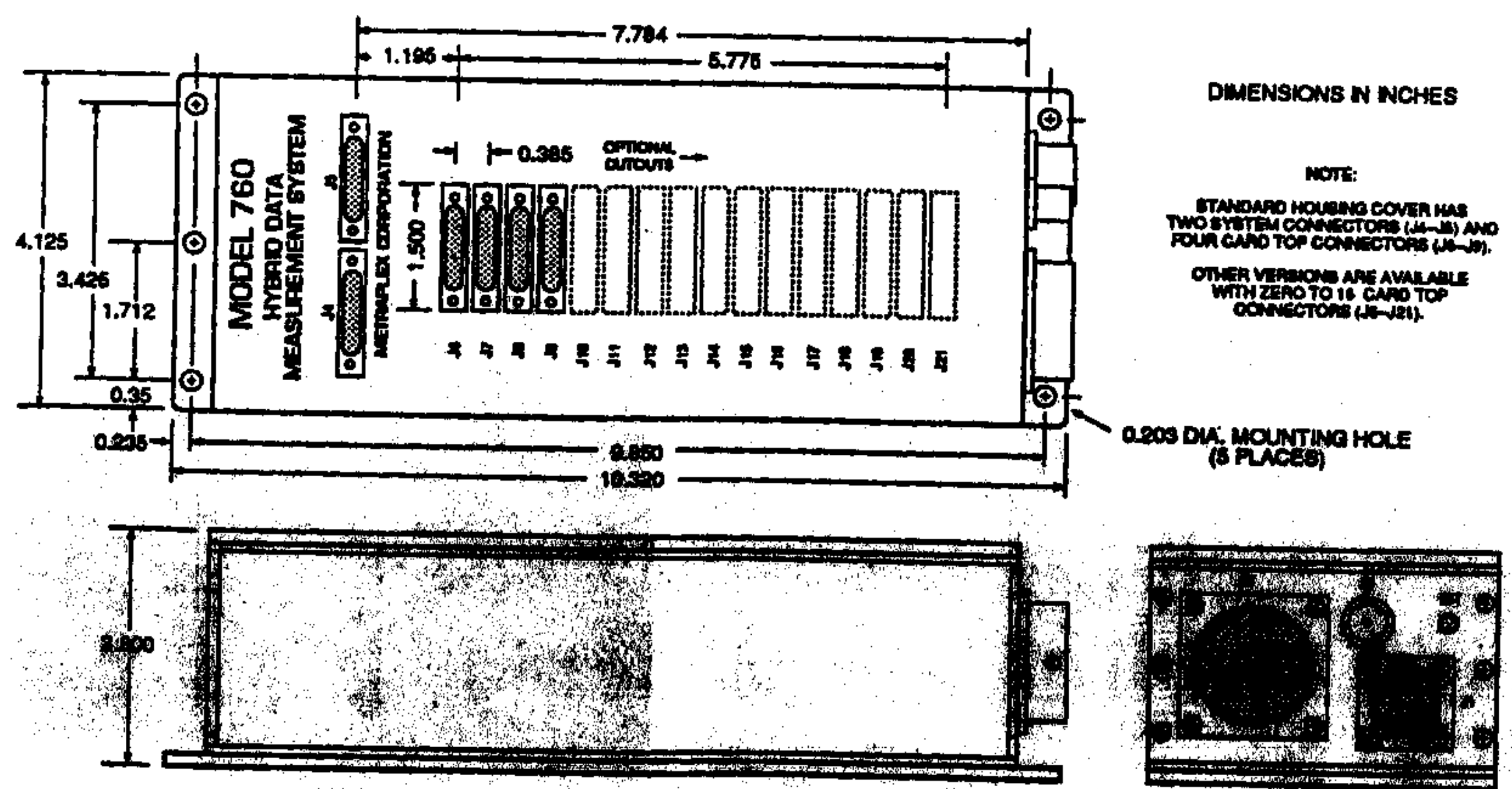


FIGURE 6. TOP DIAGRAM OF METRAPLEX HYBRID HIGH-SPEED DATA ACQUISITION SYSTEM

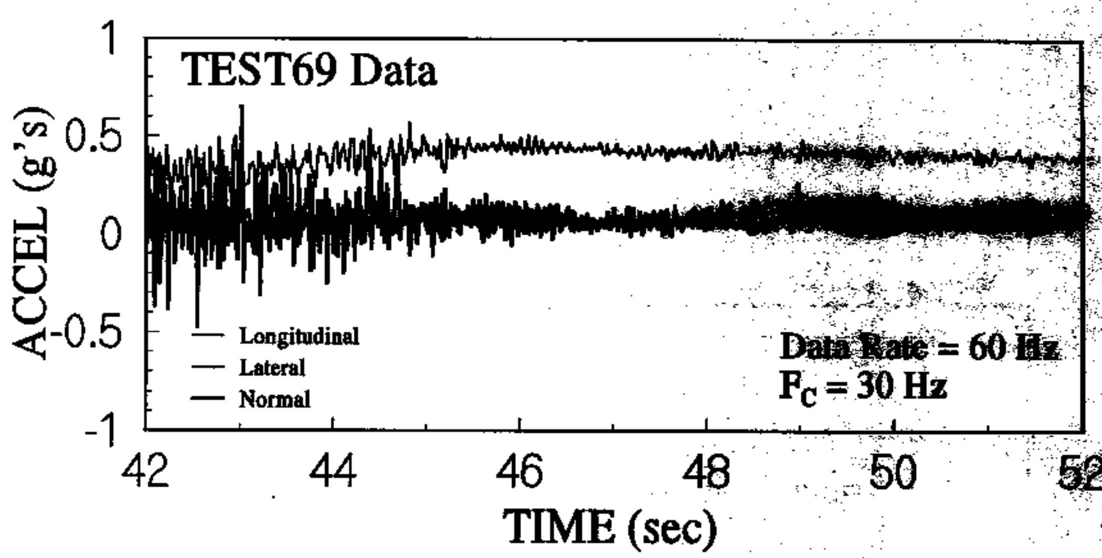


FIGURE 7. EXAMPLE TO ILLUSTRATE EFFECT OF THE FILTER; $F_c = 30$ HZ

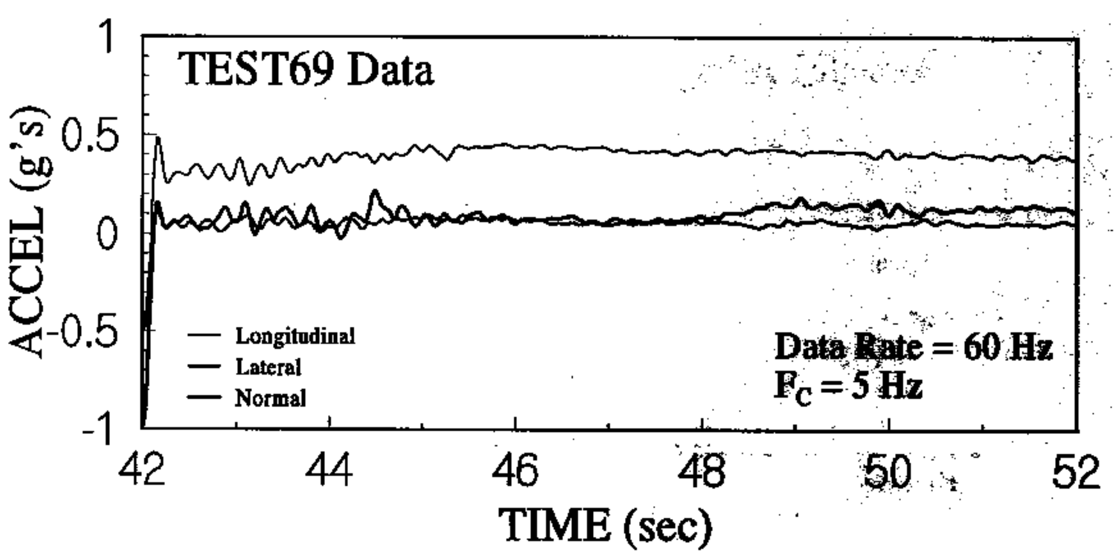


FIGURE 8. EXAMPLE TO ILLUSTRATE EFFECT OF THE FILTER; $F_c = 5$ HZ

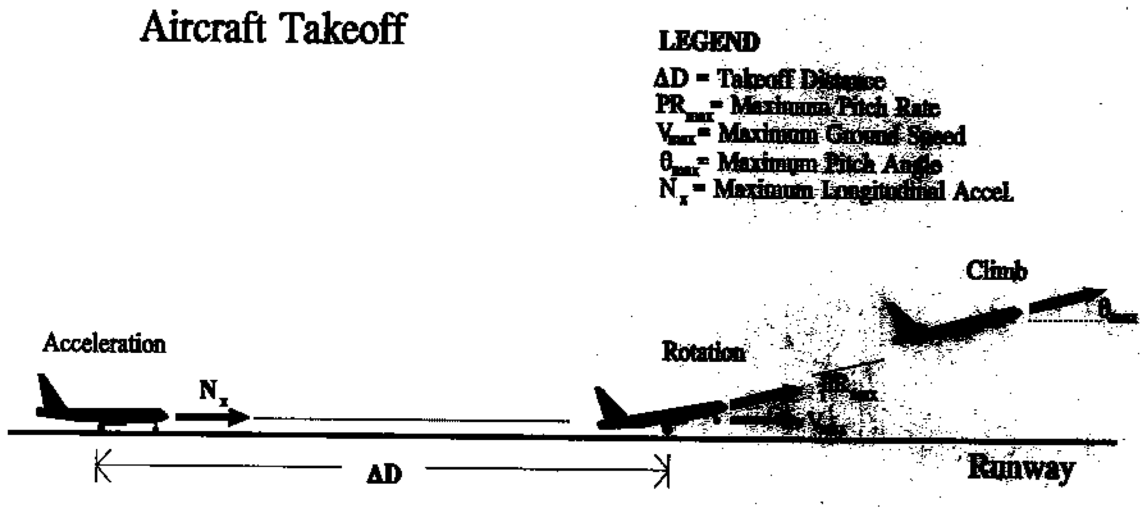


FIGURE 9. ILLUSTRATION OF SPECIFIC TAKEOFF PARAMETERS

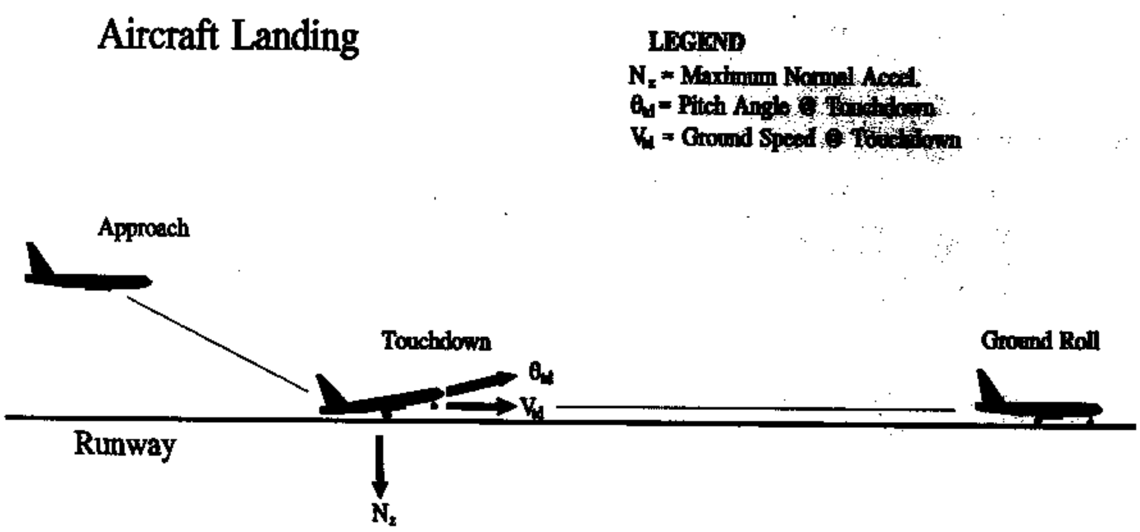


FIGURE 10. ILLUSTRATION OF SPECIFIC LANDING PARAMETERS

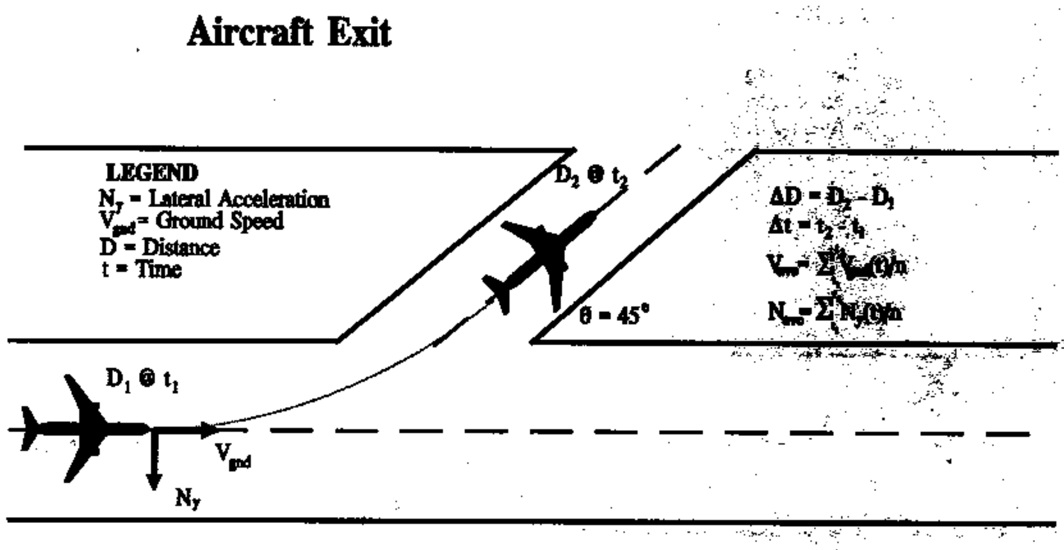


FIGURE 11. ILLUSTRATION OF SPECIFIC RUNWAY EXIT PARAMETERS

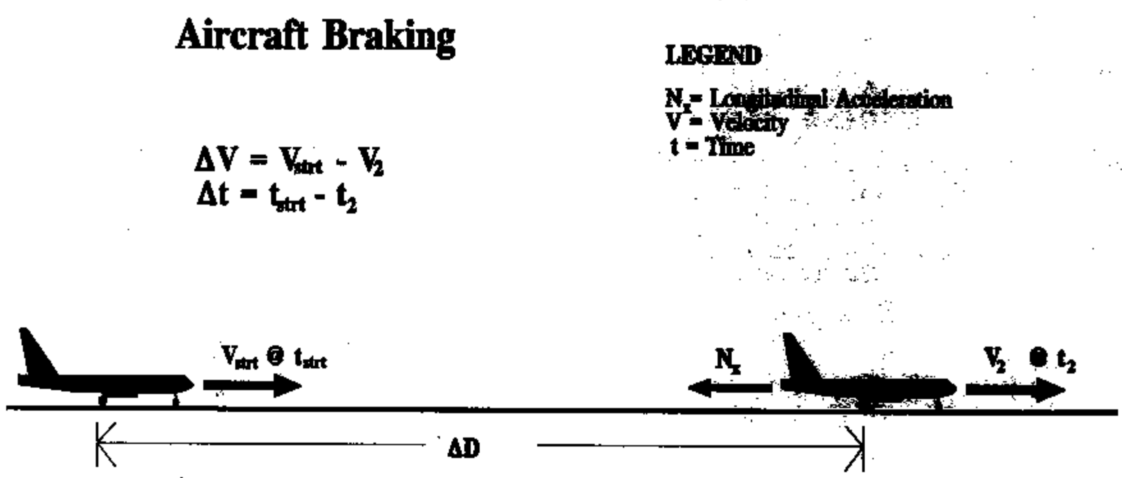


FIGURE 12. ILLUSTRATION OF SPECIFIC BRAKING PARAMETERS

Aircraft S-Turn

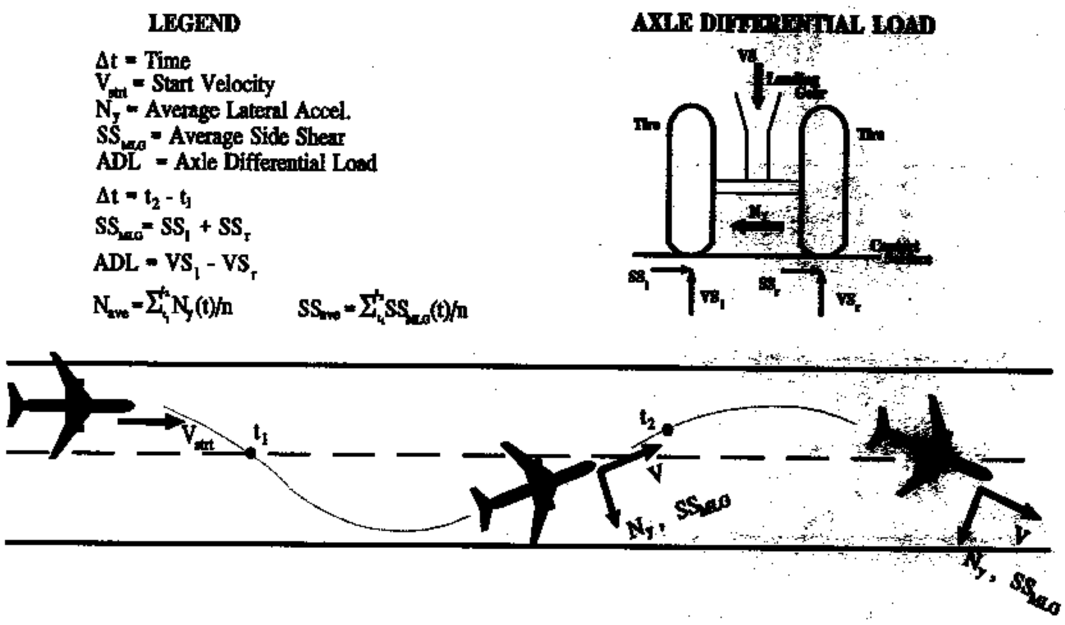


FIGURE 13. ILLUSTRATION OF SPECIFIC S-TURN PARAMETERS

Aircraft Minimum-Radius Turn

FIGURE 14. ILLUSTRATION OF SPECIFIC MINIMUM-RADIUS TURN PARAMETERS

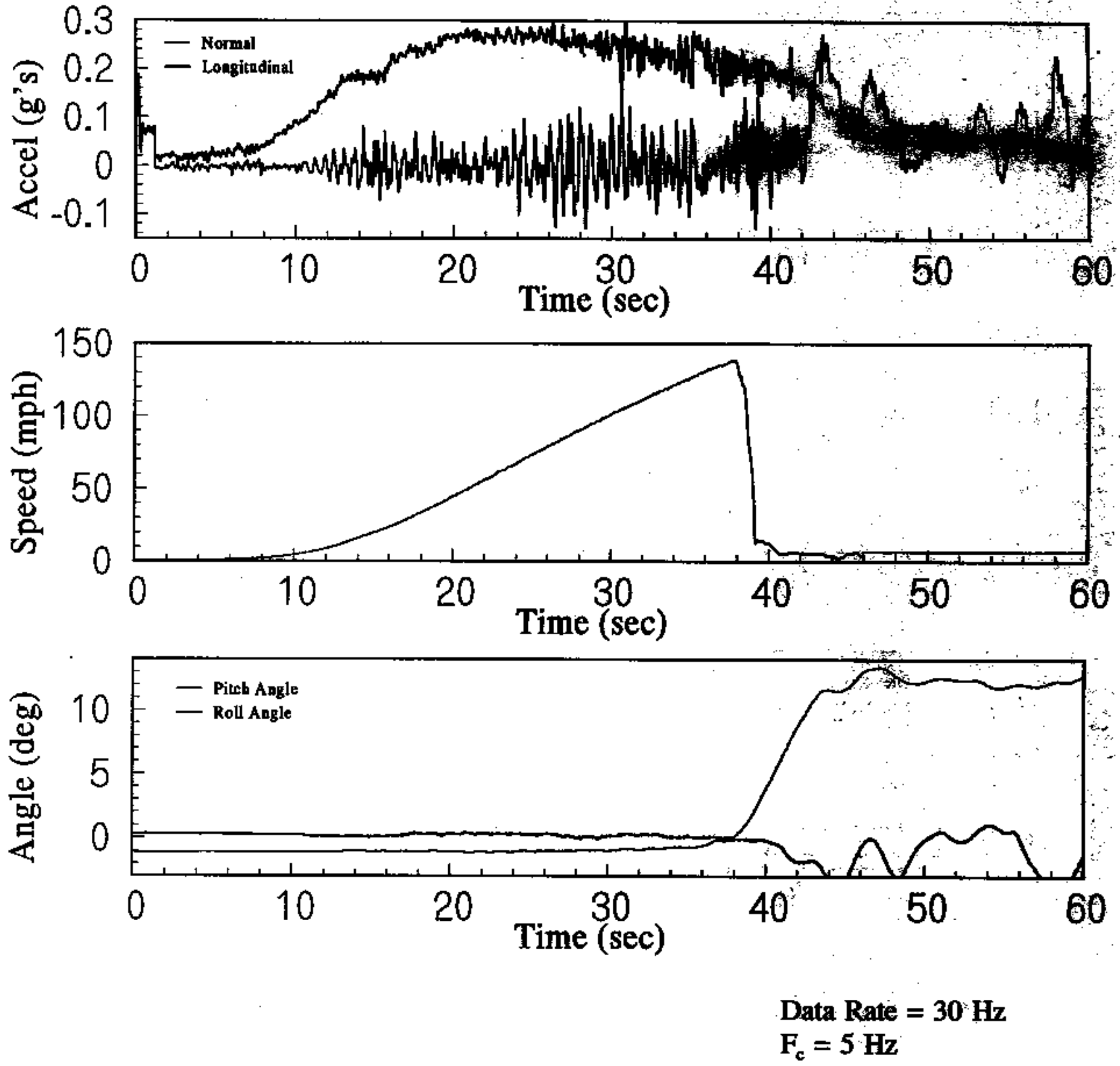
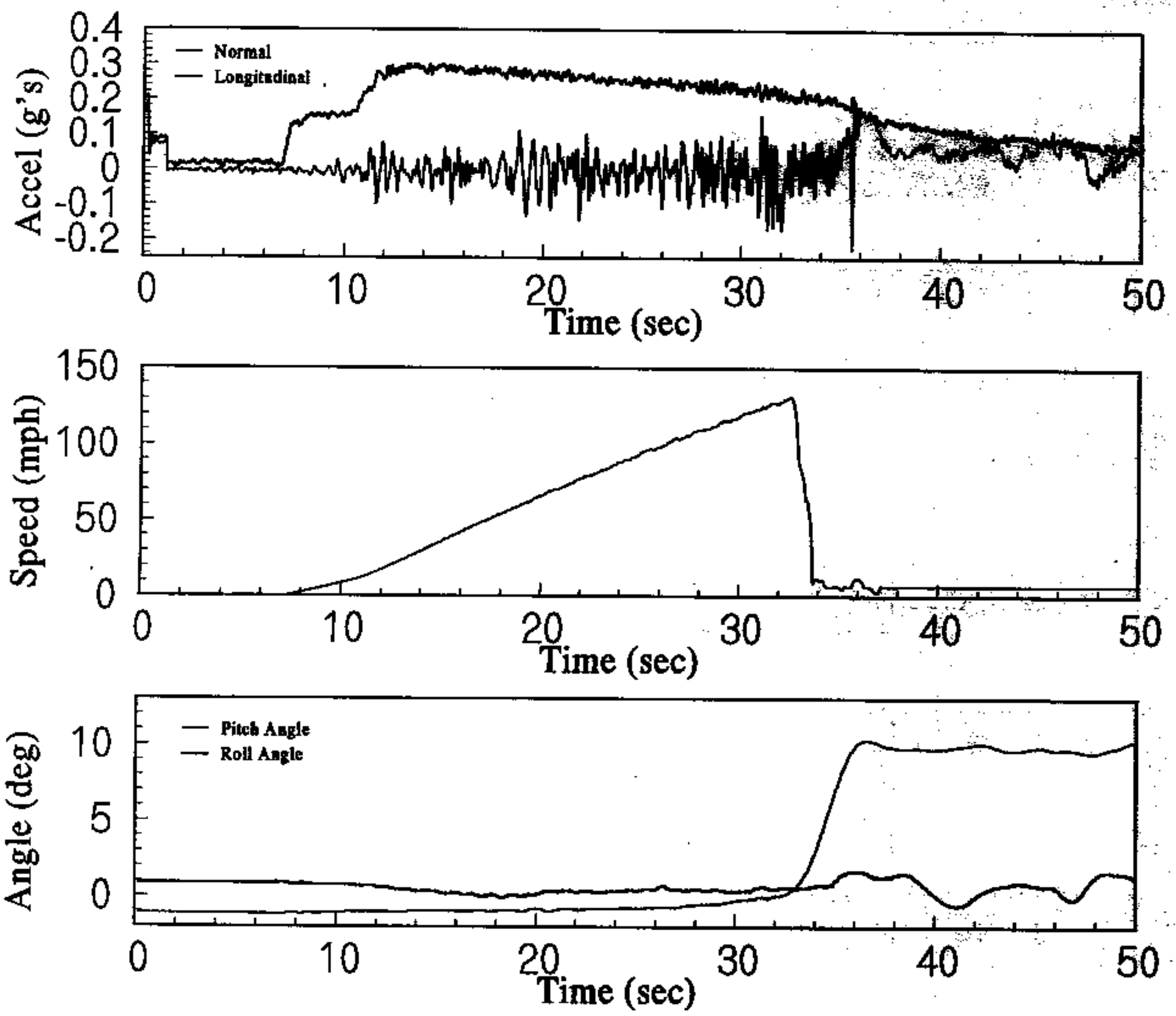


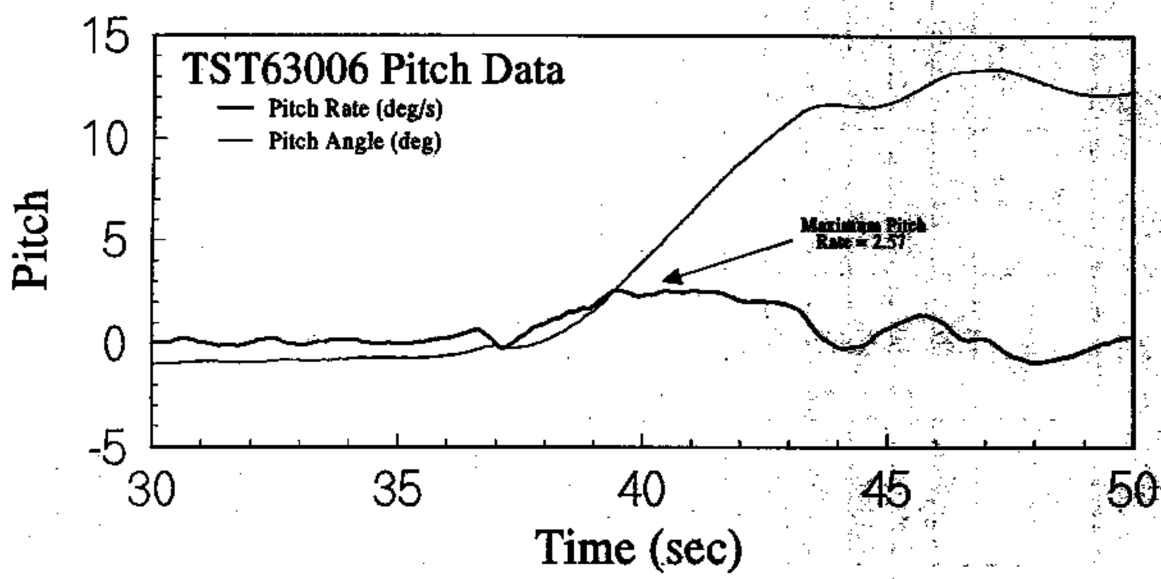
FIGURE 15. MULTIPLE TIME TRACE DATA PLOT OF A TYPICAL TAKEOFF EVENT

TST11408

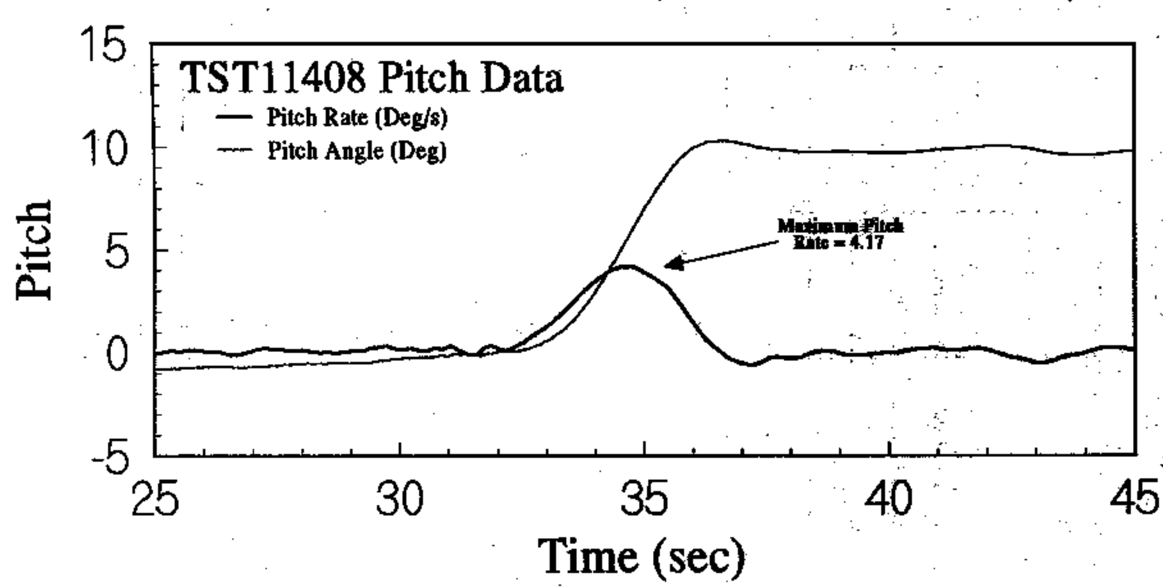


Data Rate = 30 Hz
F_c = 5 Hz

FIGURE 16. MULTIPLE TIME TRACE DATA PLOT OF A TYPICAL TAKEOFF EVENT



GRAPH 17(a)



GRAPH 17(b)

FIGURE 17. PITCH ANGLE AND PITCH RATE DATA OF TWO TYPICAL TAKEOFF EVENTS (a.) TST63006 AND (b.) TST11408

TABLE 1. TABLE OF SPECIFIC EVENT PARAMETERS FOR THE TAKEOFF EVENTS

Event Data File Name	Runway	Aircraft Weight	Wind Velocity	Wind Direction	Peak N_x	Max Speed	Adj. Speed	Runway Distance	Time to Liftoff	Max Pitch Rate	Max Pitch Angle
		(lbs)	(mph)	(deg)	(g's)	(mph)	(mph)	(ft)	(sec)	(deg/s)	(deg)
TEST4	ACY-13	126326	8	360	0.27	124.0	130.13	2708.0	32.25	X	X
TEST9	ACY-13	128226	0	0	0.29	135.2	135.20	3181.6	29.88	X	X
TEST11	ACY-13	126826	0	0	0.29	133.6	133.60	2892.0	32.25	X	X
TEST13	ACY-13	124226	4	320	0.30	128.9	132.84	2884.5	34.6	X	X
TEST15	ACY-13	122926	5	330	0.31	128.5	133.20	2986.3	37.4	X	X
TEST17	ACY-13	121226	5	350	0.285	130.4	134.23	X	X	X	X
TEST19	ACY-13	119426	5	10	0.31	130.0	133.21	X	X	X	X
TEST22	ACY-13	116726	4	20	0.31	128.7	130.70	X	X	X	X
TEST600	ACY-31	131526	0	0	0.355	127.3	137.30	3096.6	34.3	X	X
TST62910	IAD-30	130926	10	200	0.22	138.7	136.96	X	X	2.67	14.5
TST63006	ACY-31	128126	15	200	0.27	138.3	133.17	3333.1	37.73	2.57	13.5
TST63009	ACY-13	125526	10	180	0.24	133.6	140.03	3289.5	34.78	2.75	14.0
TST63012	ACY-13	123526	14	180	0.285	123.6	132.60	2588.6	24.53	2.74	15.0
TEST61	ACY-31	130426	0	0	0.285	133.5	133.50	3117.8	34.6	3.09	16.5
TEST65	ACY-31	126126	0	0	0.30	137.7	137.70	3030.2	30.7	4.11	17.0
TEST67	ACY-31	123726	5	170	0.37	140.3	136.47	2970.4	23.17	4.63	18.0
TEST69	ACY-13	121926	5	220	0.34	133.6	133.60	2763.0	30.22	4.40	17.0
TST92203	ACY-13	X	X	X	0.26	130.3	X	2927.3	33.55	3.12	14.0
TST11401	JFK-311	X	X	X	0.235	126.9	X	3511.7	37.75	3.17	15.0
TST11408	JFK-311	X	X	X	0.29	131.7	X	2822.2	28.20	4.17	10.5
TST51911	DFW-31l	X	X	X	0.30	142.2	X	3570.3	30.91	3.61	15.0
TST51906	DFW-13r	X	X	X	0.285	134.1	X	3227.6	27.3	3.66	14.5

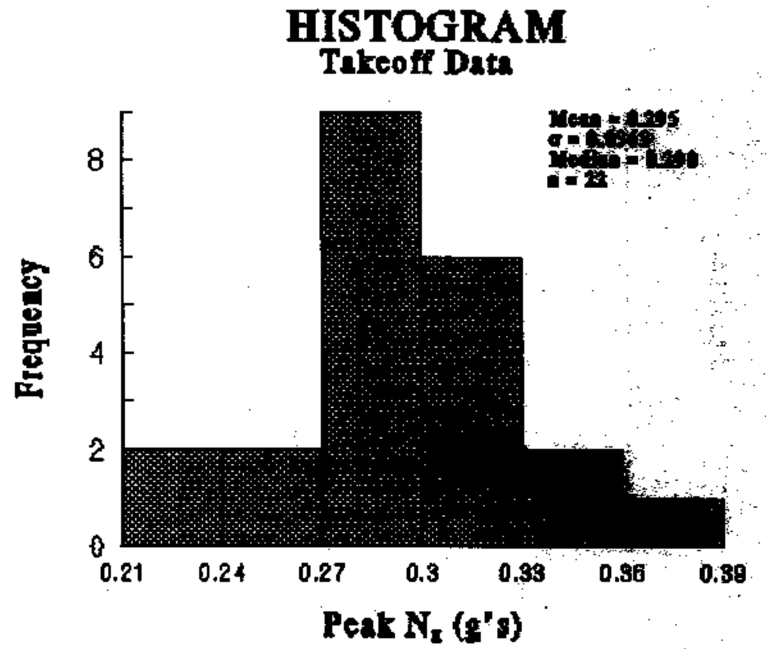


FIGURE 18. HISTOGRAM OF TAKEOFF LONGITUDINAL ACCELERATION SPECIFIC EVENT VALUES

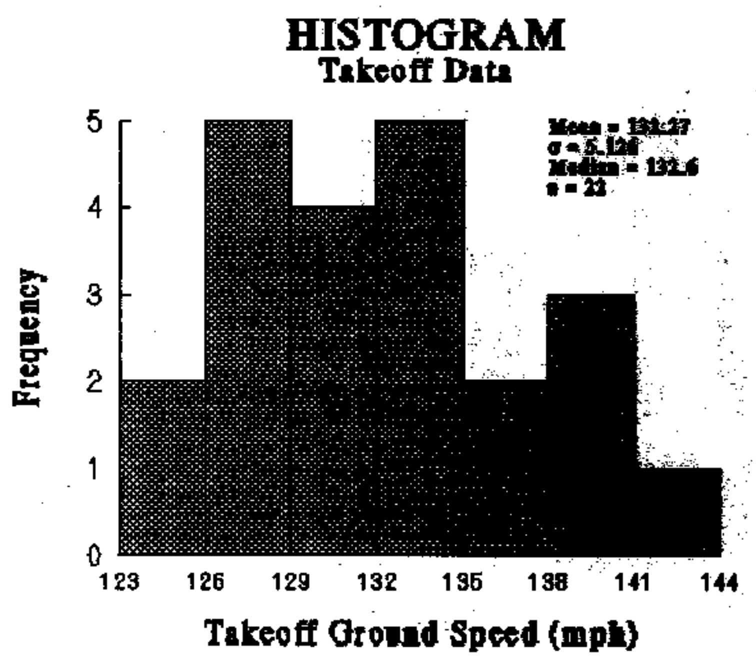


FIGURE 19. HISTOGRAM OF TAKEOFF GROUND SPEED SPECIFIC EVENT VALUES

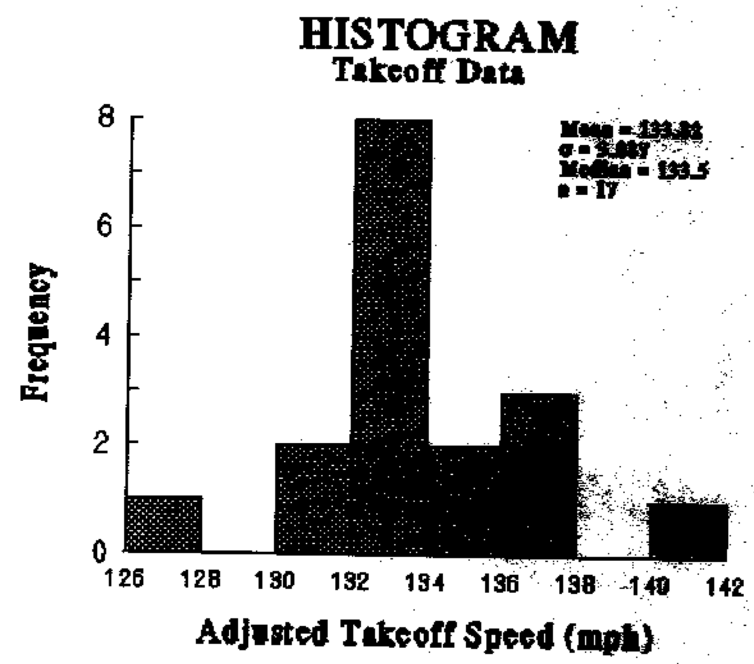


FIGURE 20. HISTOGRAM OF ADJUSTED TAKEOFF SPEED SPECIFIC EVENT VALUES

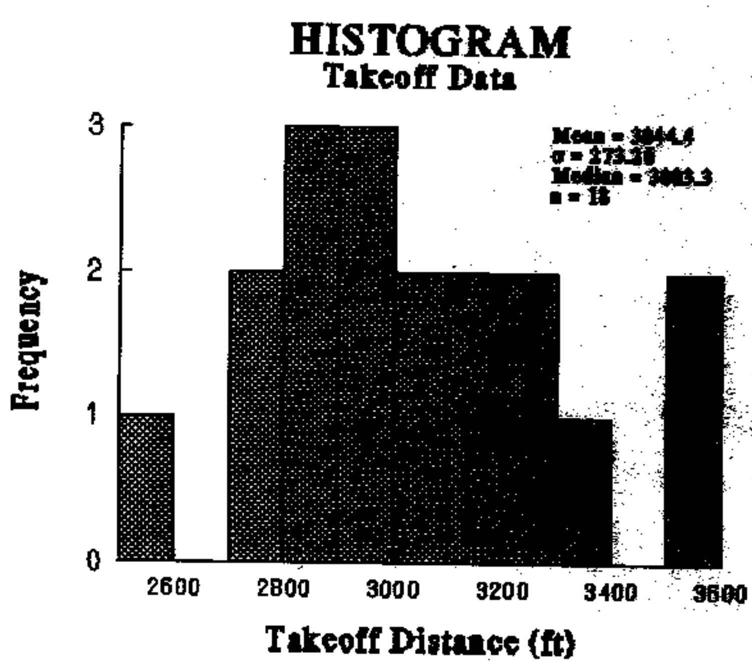


FIGURE 21. HISTOGRAM OF TAKEOFF DISTANCE SPECIFIC EVENT VALUES

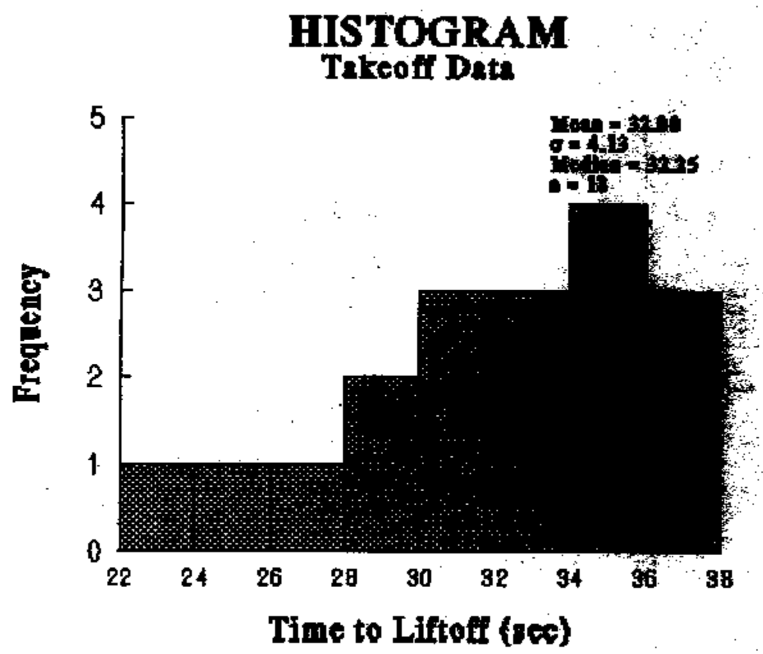


FIGURE 22. HISTOGRAM OF TAKEOFF TIME TO LIFTOFF SPECIFIC EVENT VALUES

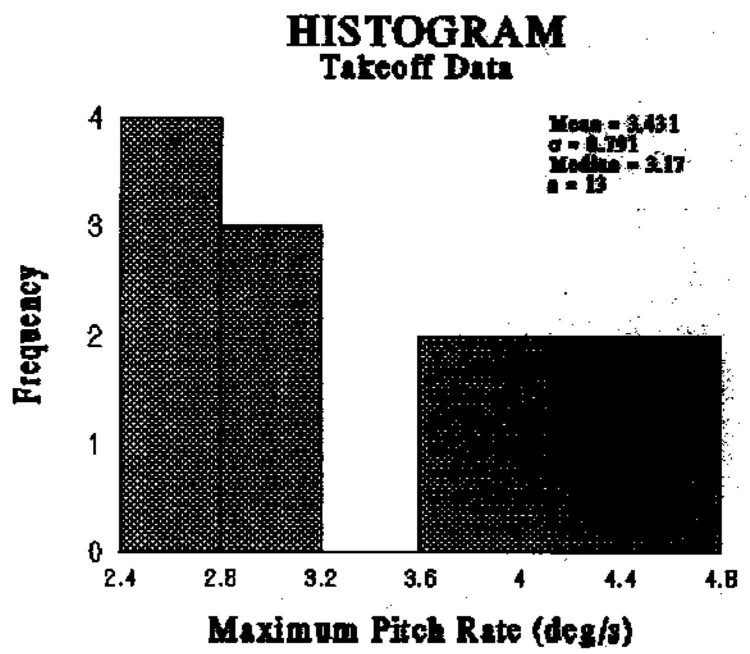


FIGURE 23. HISTOGRAM OF TAKEOFF MAXIMUM PITCH RATE SPECIFIC EVENT VALUES

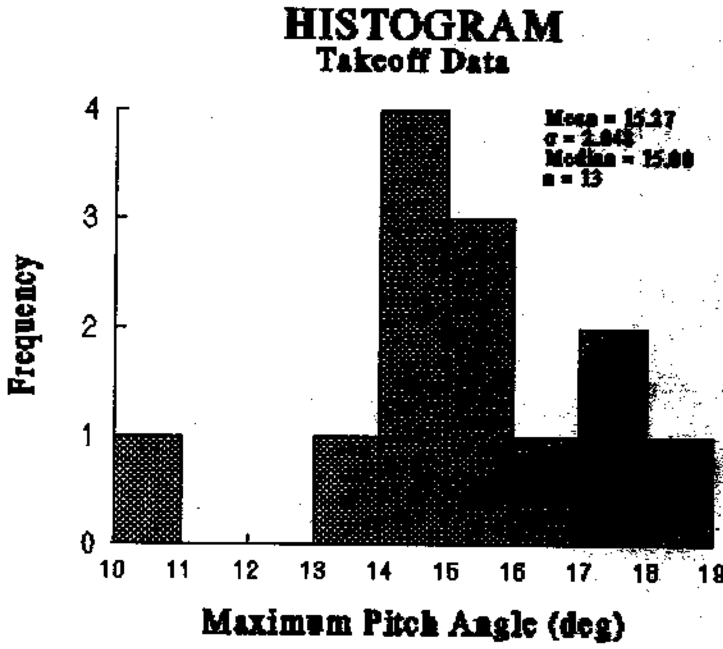


FIGURE 24. HISTOGRAM OF TAKEOFF MAXIMUM PITCH ANGLE SPECIFIC EVENT VALUES

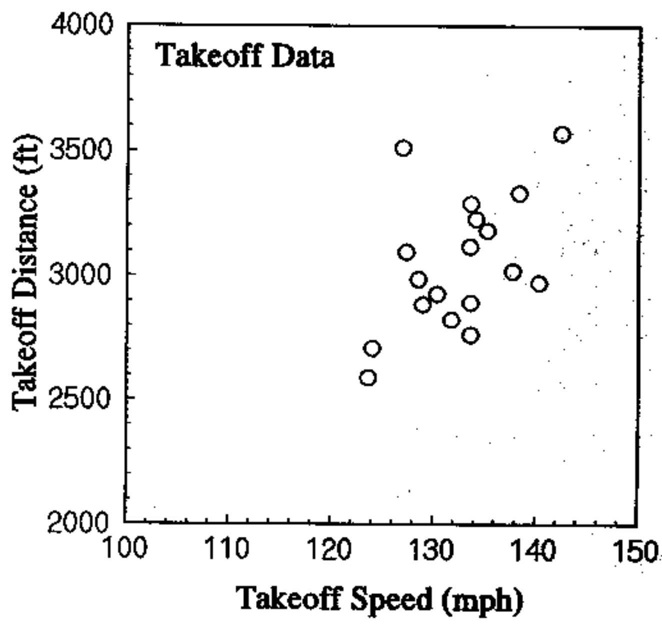


FIGURE 25. CORRELATION PLOT OF TAKEOFF DISTANCE AND TAKEOFF SPEED

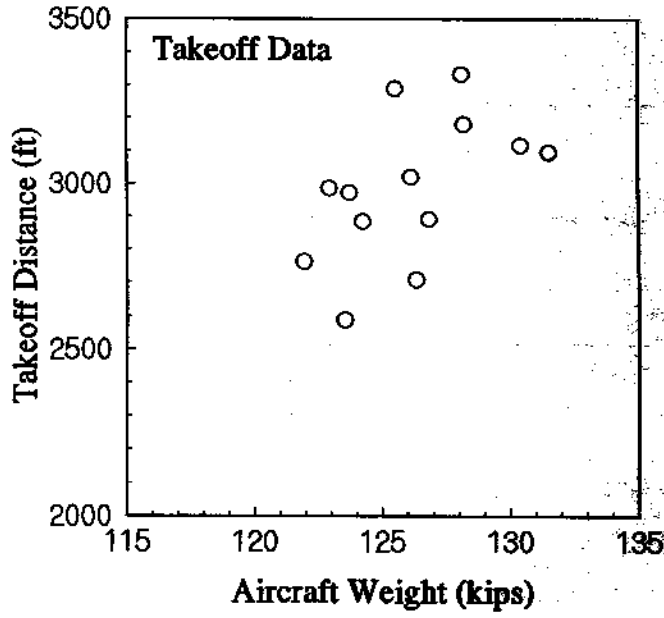


FIGURE 26. CORRELATION PLOT OF TAKEOFF DISTANCE AND AIRCRAFT WEIGHT

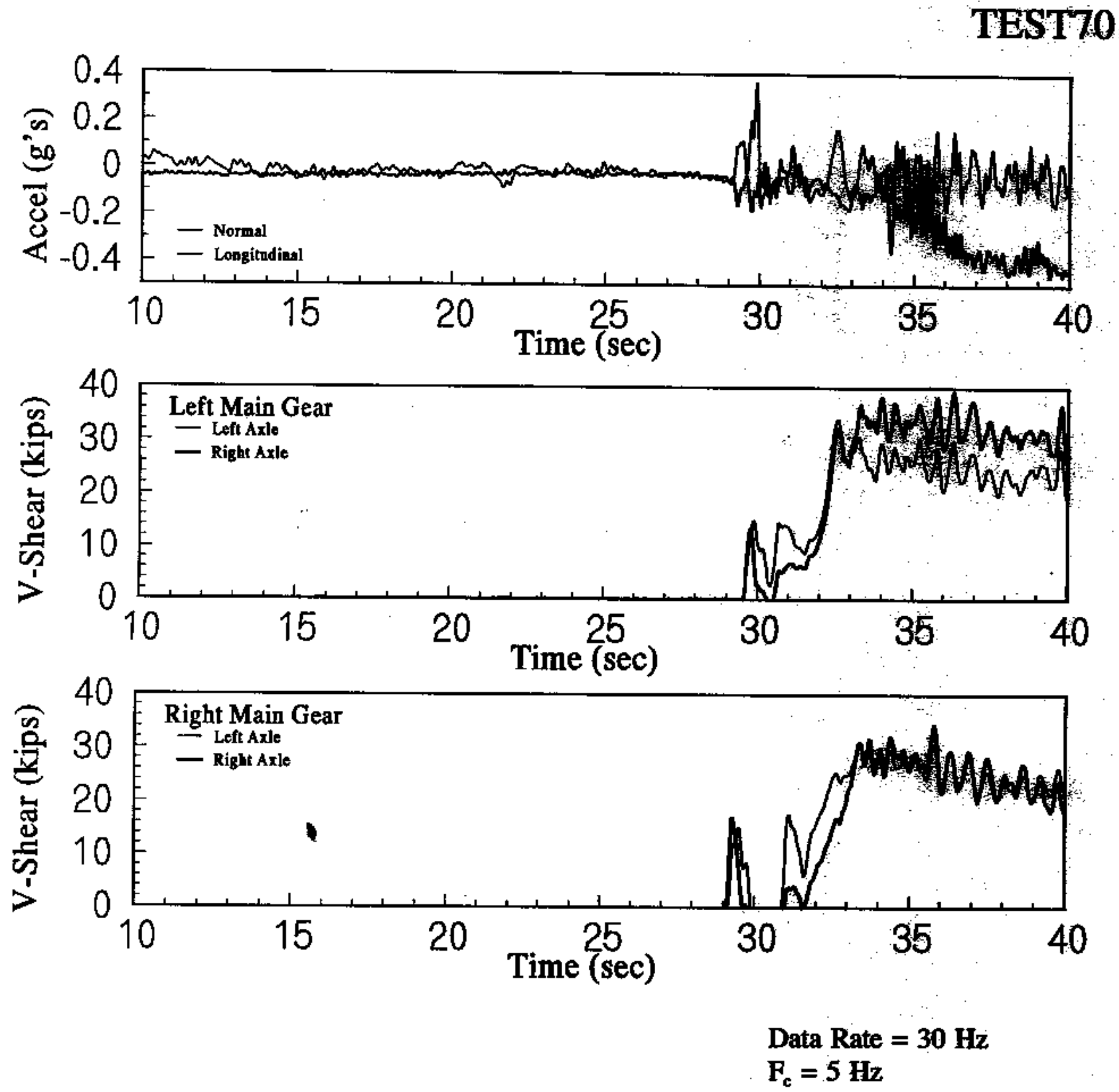
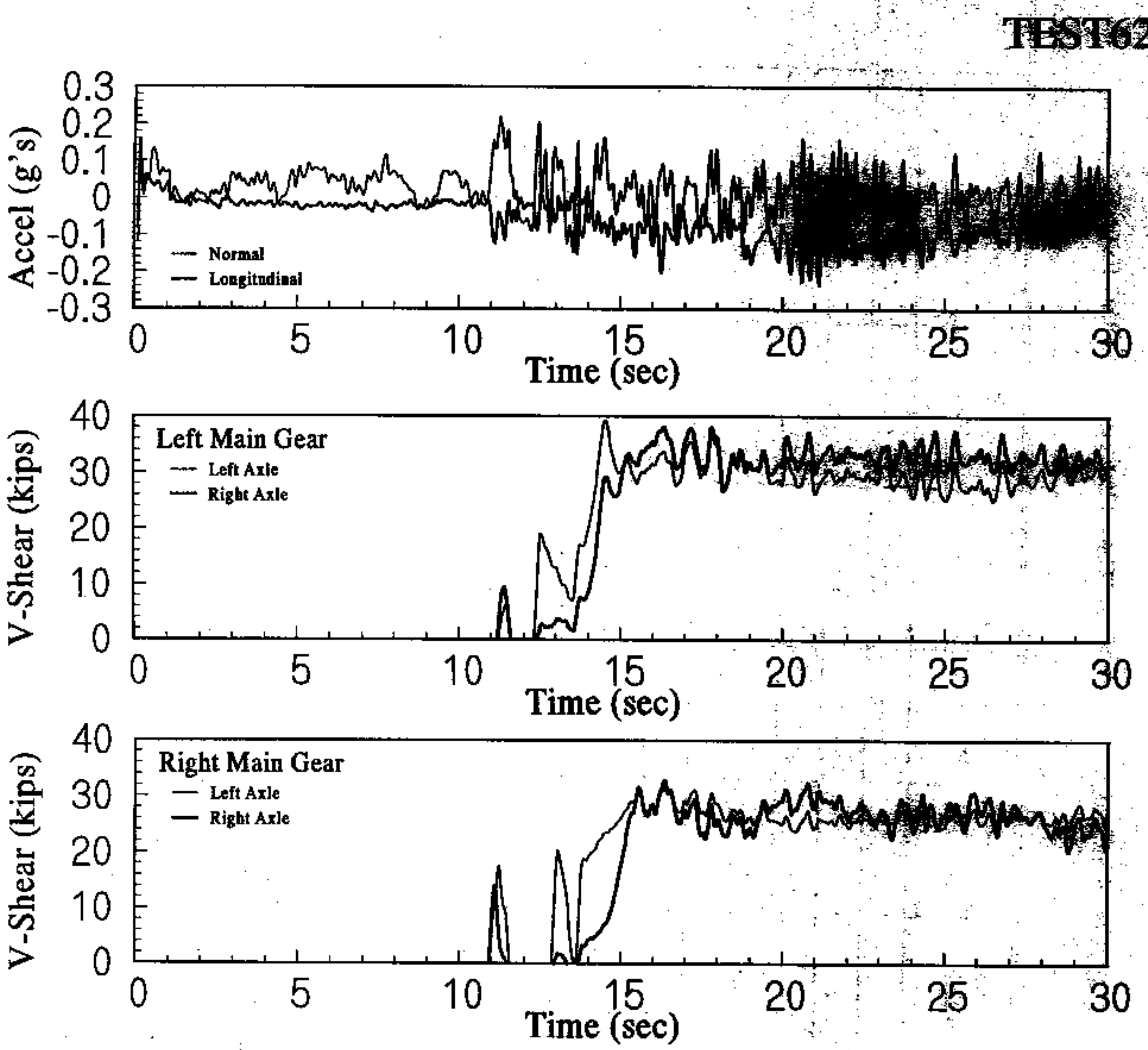


FIGURE 27. MULTIPLE TIME TRACE DATA PLOT OF A TYPICAL LANDING EVENT



Data Rate = 30 Hz
F_c = 5 Hz

FIGURE 28. MULTIPLE TIME TRACE DATA PLOT OF A TYPICAL LANDING EVENT

TABLE 2. TABLE OF SPECIFIC EVENT PARAMETERS FOR THE LANDING EVENTS

Event Data File Name	Runway	Aircraft Weight	Wind Velocity	Wind Direction	Touchdown Pitch Angle	Touchdown Speed	Adjusted Speed	Touch-down N_z	Touchdown MLG Shear
		(lbs)	(mph)	(deg)	(deg)	(mph)	(mph)	(g's)	(kips)
TST63007	ACY-13	127426	15	200	5.10	140.3	135.17	0.192	30.74
TST63010	ACY-13	124826	10	180	4.00	144.5	138.07	0.185	39.79
TST63013	ACY-13	122826	10	180	4.60	137.3	130.87	0.143	29.09
TST11402	JKF-131	127500	X	X	7.10	122.8	X	0.406	52.62
TEST68	ACY-13	122826	4	210	6.76	124.3	123.61	0.179	21.00
TEST62	ACY-13	129826	7	220	5.82	137.9	137.90	0.219	26.15
TEST64	ACY-13	126726	0	0	5.29	136.3	136.30	0.136	27.45
TEST70	ACY-31	119226	5	180	3.50	126.4	129.61	0.363	34.05
TEST66	ACY-13	124826	5	170	5.60	134.5	130.67	0.250	31.73
TEST5	ACY-31	124326	8	350	X	146.0	139.87	0.237	29.71
TEST8	ACY-31	128226	0	0	X	154.8	154.80	0.325	44.07
TEST10	ACY-31	127126	0	0	X	147.5	147.50	0.222	33.60
TEST12	ACY-31	124926	0	0	X	155.5	155.50	0.227	25.81
TEST14	ACY-31	123126	5	350	X	130.1	126.27	0.474	65.20
TEST16	ACY-31	121226	5	330	X	134.6	130.77	0.350	59.10
TEST18	ACY-31	119726	5	20	X	133.0	131.29	0.294	30.13
TEST20	ACY-31	118226	4	20	X	133.2	131.83	0.364	54.25
TEST23	ACY-31	114626	5	340	X	130.1	125.77	0.327	27.74

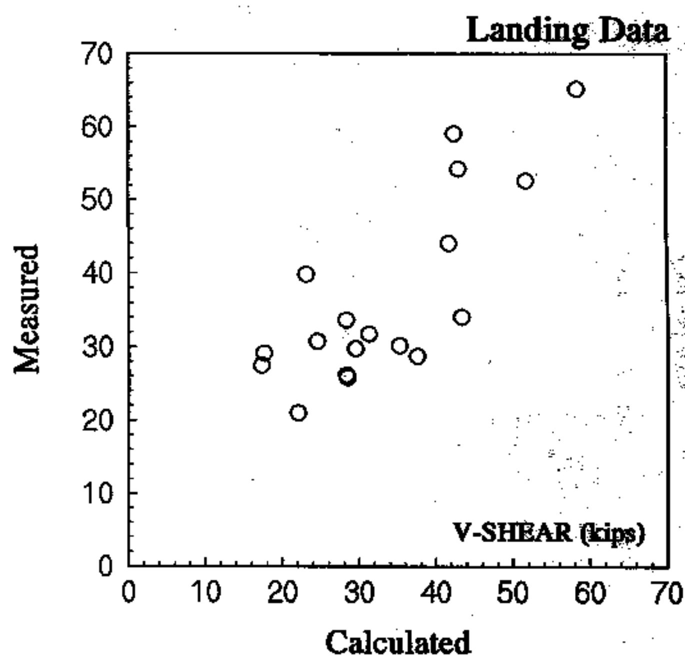


FIGURE 29. COMPARISON OF MEASURED AND CALCULATED VERTICAL SHEAR AT TOUCHDOWN

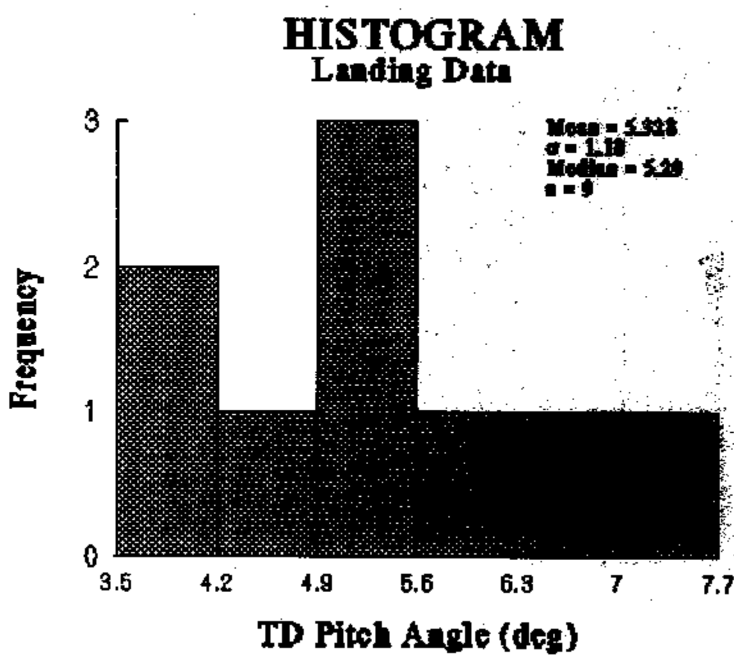


FIGURE 30. HISTOGRAM OF LANDING TOUCHDOWN PITCH ANGLE SPECIFIC EVENT VALUES

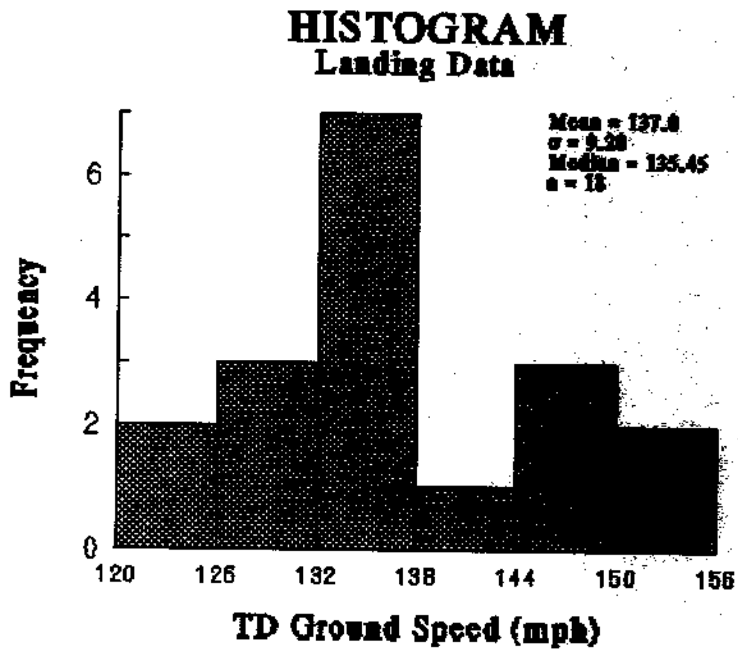


FIGURE 31. HISTOGRAM OF LANDING TOUCHDOWN GROUND SPEED SPECIFIC EVENT VALUES

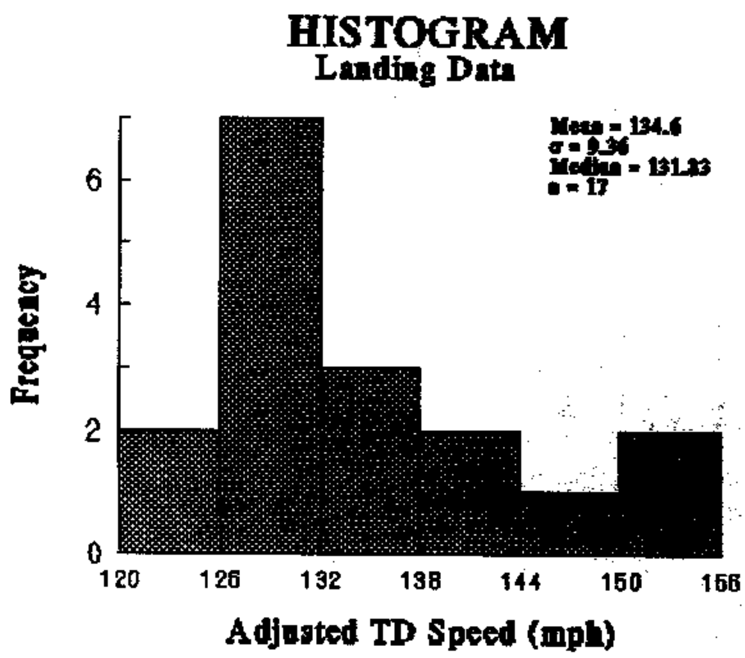


FIGURE 32. HISTOGRAM OF LANDING ADJUSTED TOUCHDOWN SPEED SPECIFIC EVENT VALUES

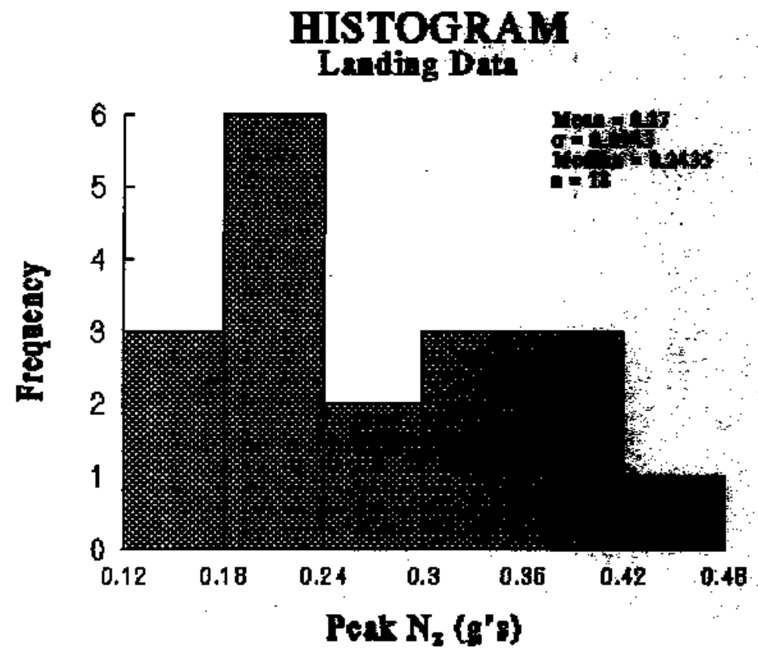


FIGURE 33. HISTOGRAM OF LANDING NORMAL ACCELERATION SPECIFIC EVENT VALUES

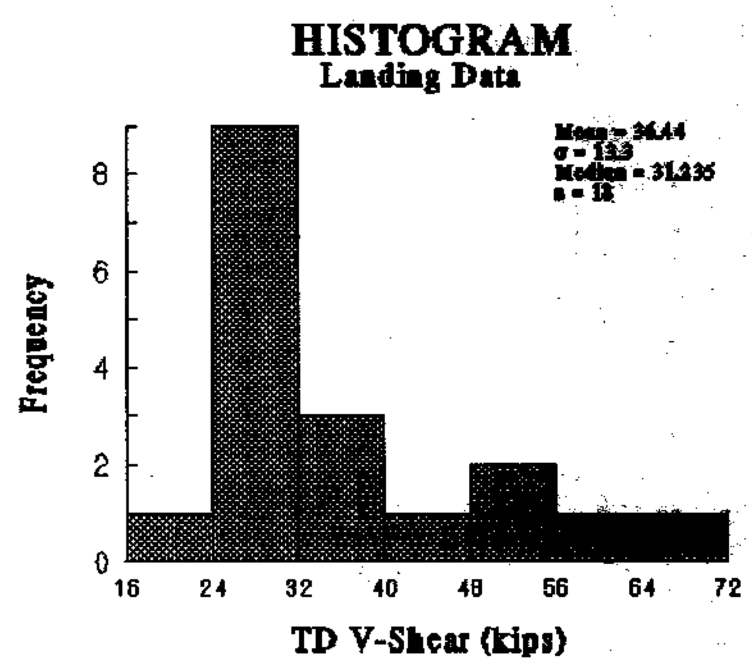


FIGURE 34. HISTOGRAM OF LANDING TOUCHDOWN VERTICAL SHEAR SPECIFIC EVENT VALUES

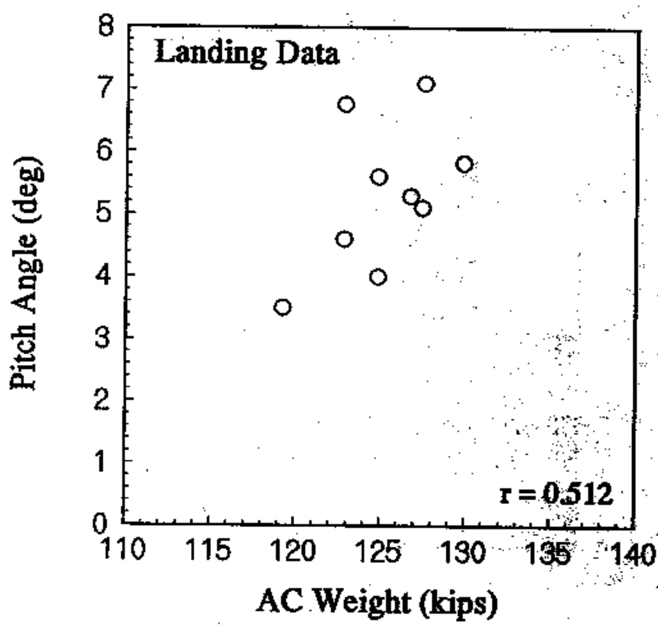


FIGURE 35. CORRELATION PLOT OF PITCH ANGLE AND AIRCRAFT WEIGHT AT TOUCHDOWN

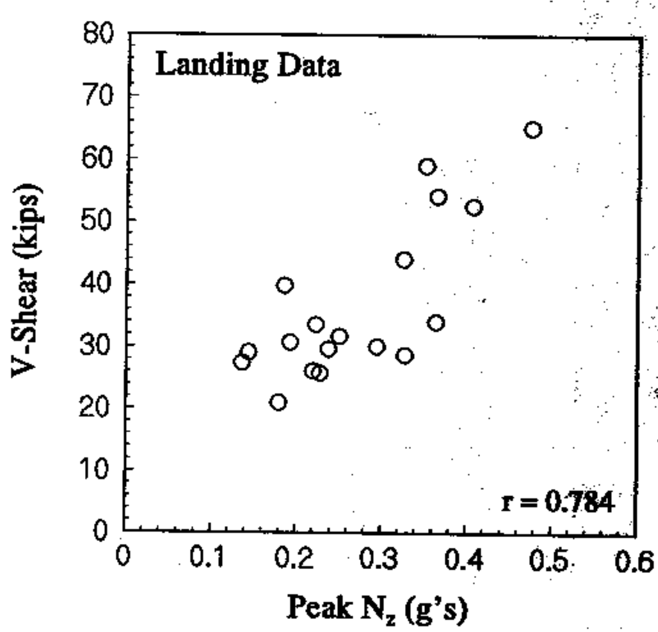
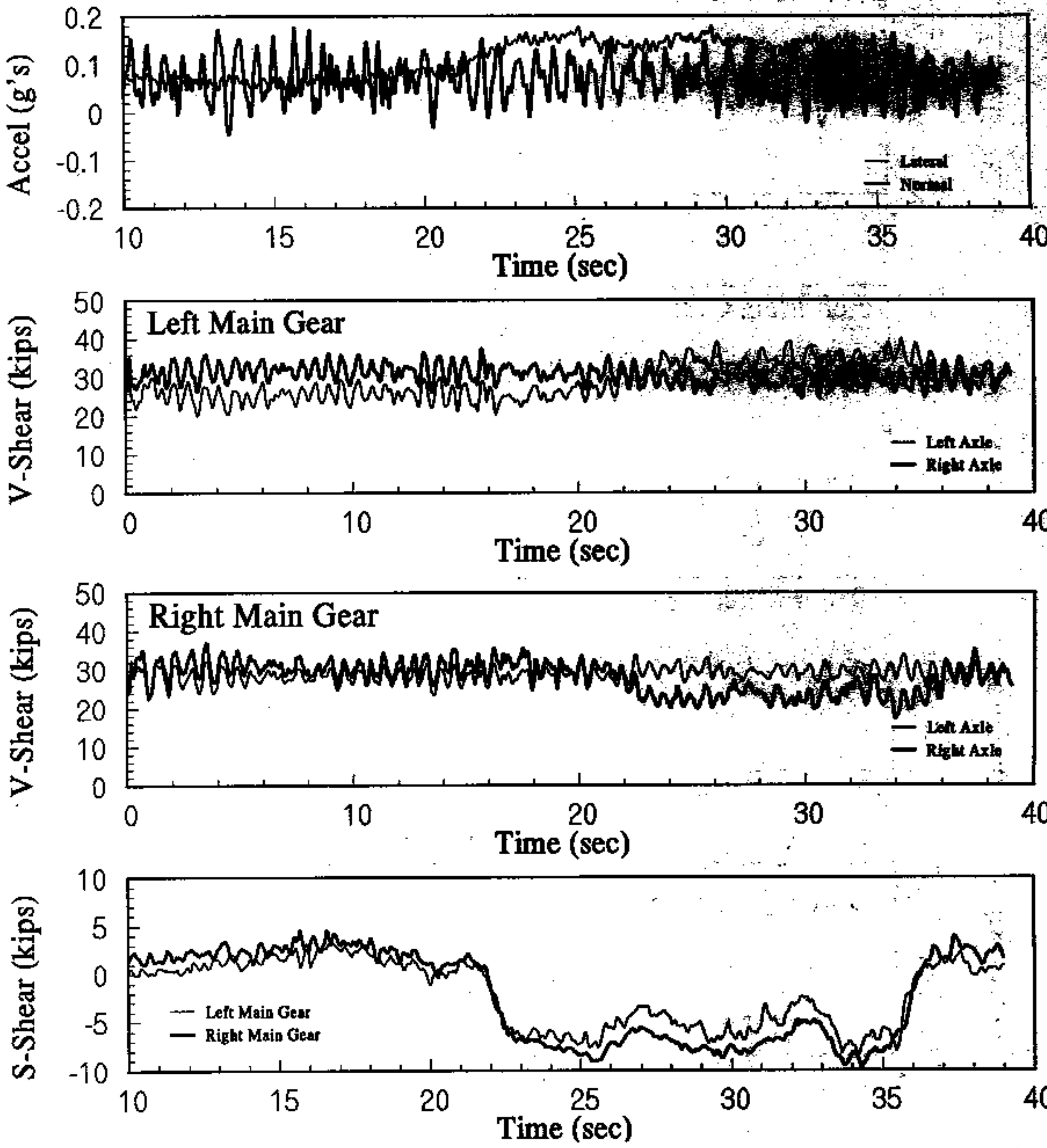
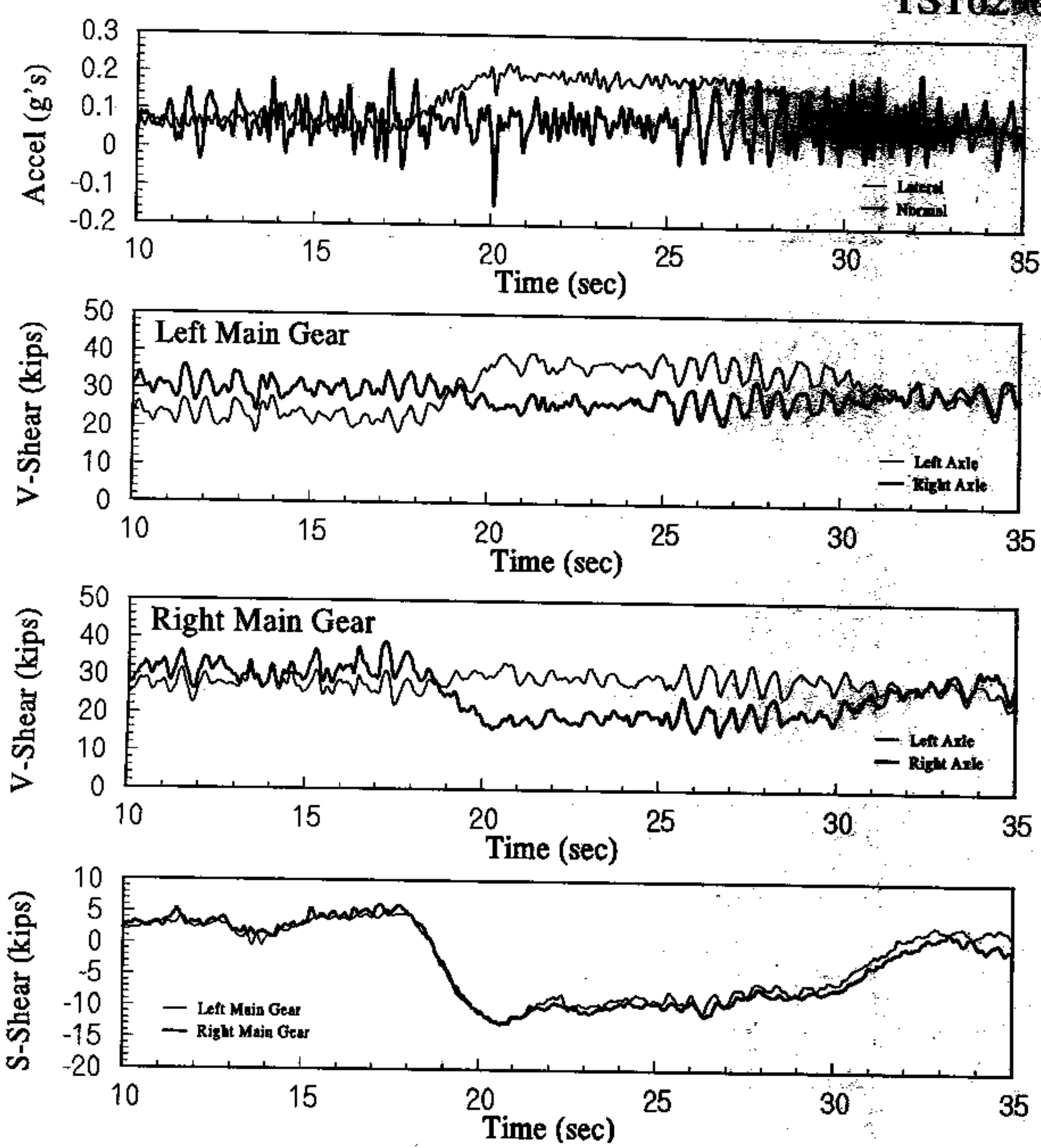


FIGURE 36. CORRELATION PLOT OF VERTICAL SHEAR AND NORMAL ACCELERATION AT TOUCHDOWN



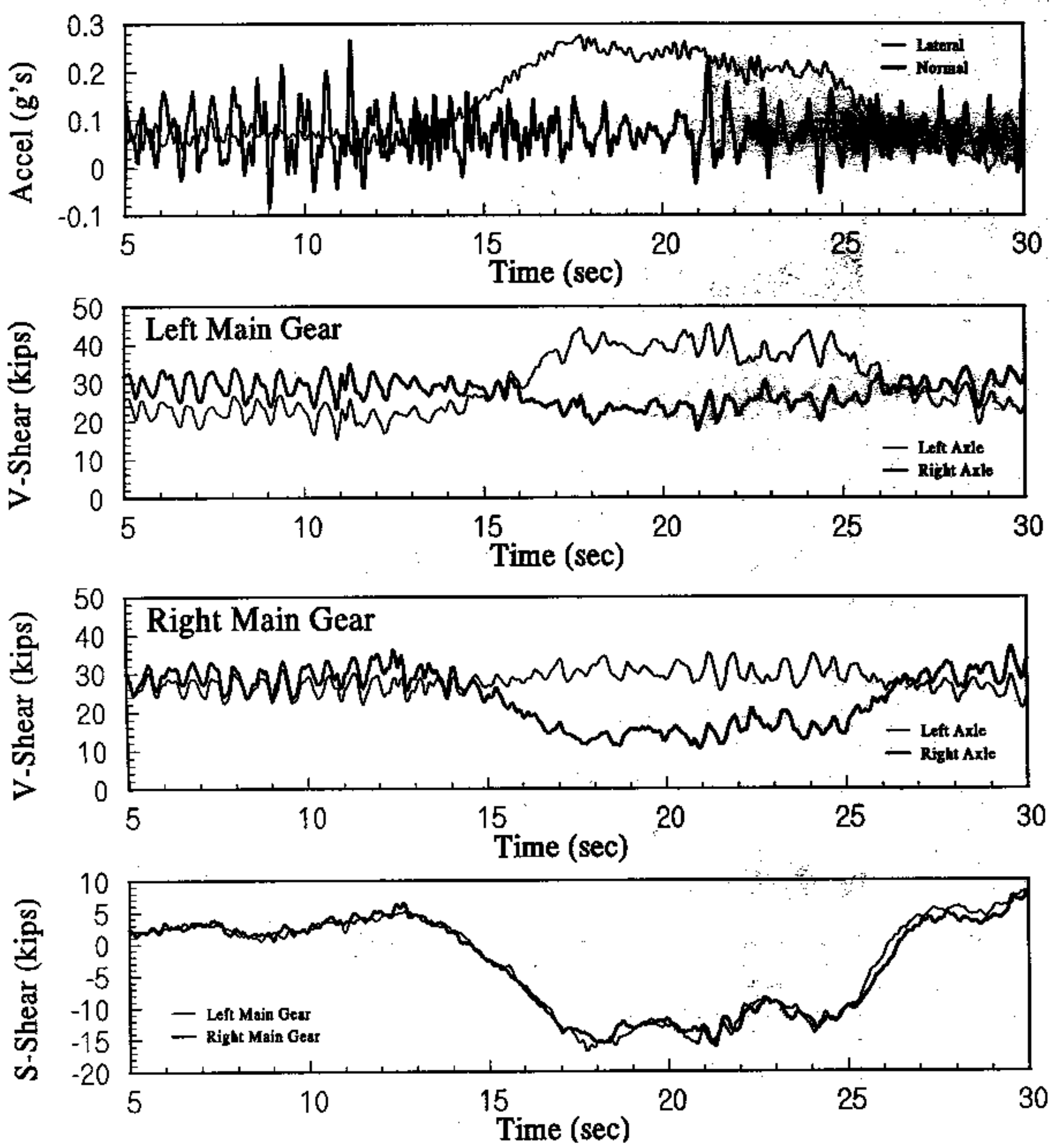
Data Rate = 30 Hz
F_c = 5 Hz

FIGURE 37. MULTIPLE TIME TRACE DATA PLOT OF A TYPICAL RUNWAY EXIT AT 40 KNOTS



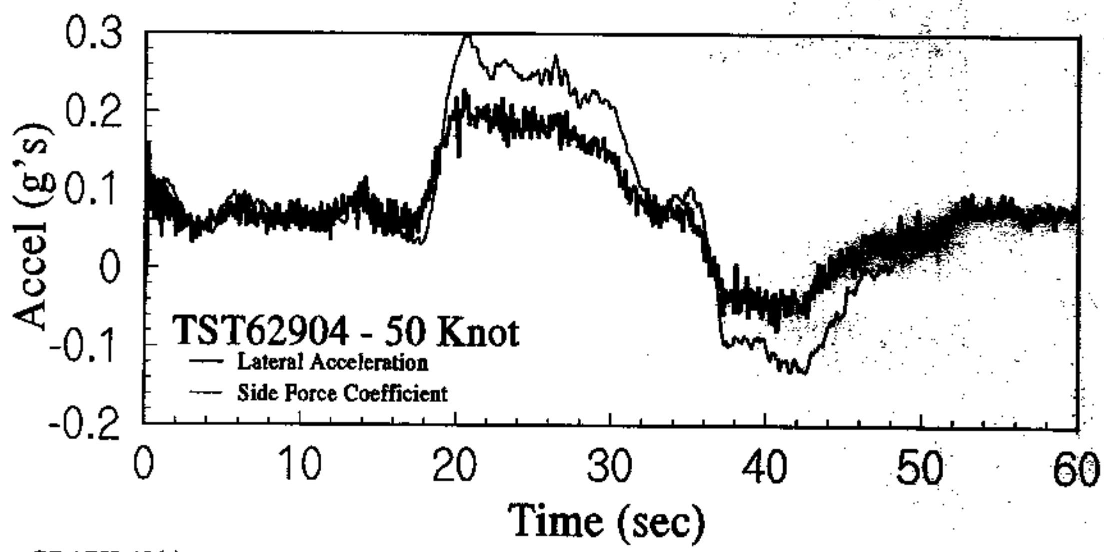
Data Rate = 30 Hz
F_c = 5 Hz

FIGURE 38. MULTIPLE TIME TRACE DATA PLOT OF A TYPICAL RUNWAY EXIT AT 50 KNOTS

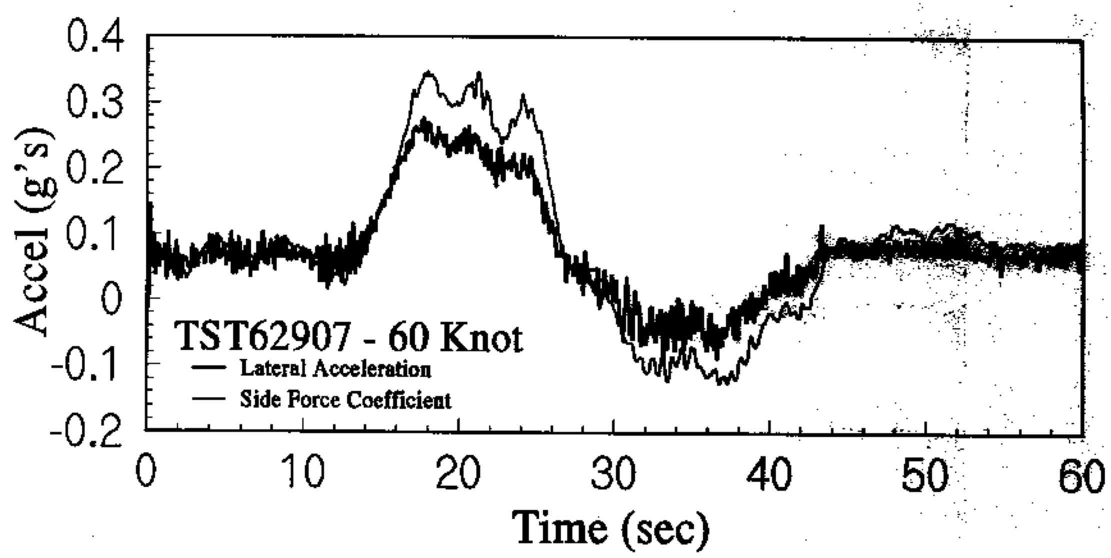


Data Rate = 30 Hz
F_c = 5 Hz

FIGURE 39. MULTIPLE TIME TRACE DATA PLOT OF A TYPICAL RUNWAY EXIT AT 60 KNOTS



GRAPH 40(a)



GRAPH 40(b)

FIGURE 40. COMPARISON IN TIME OF SIDE FORCE COEFFICIENT AND LATERAL ACCELERATION FOR (a.) TST62904 AND (b.) TST62907

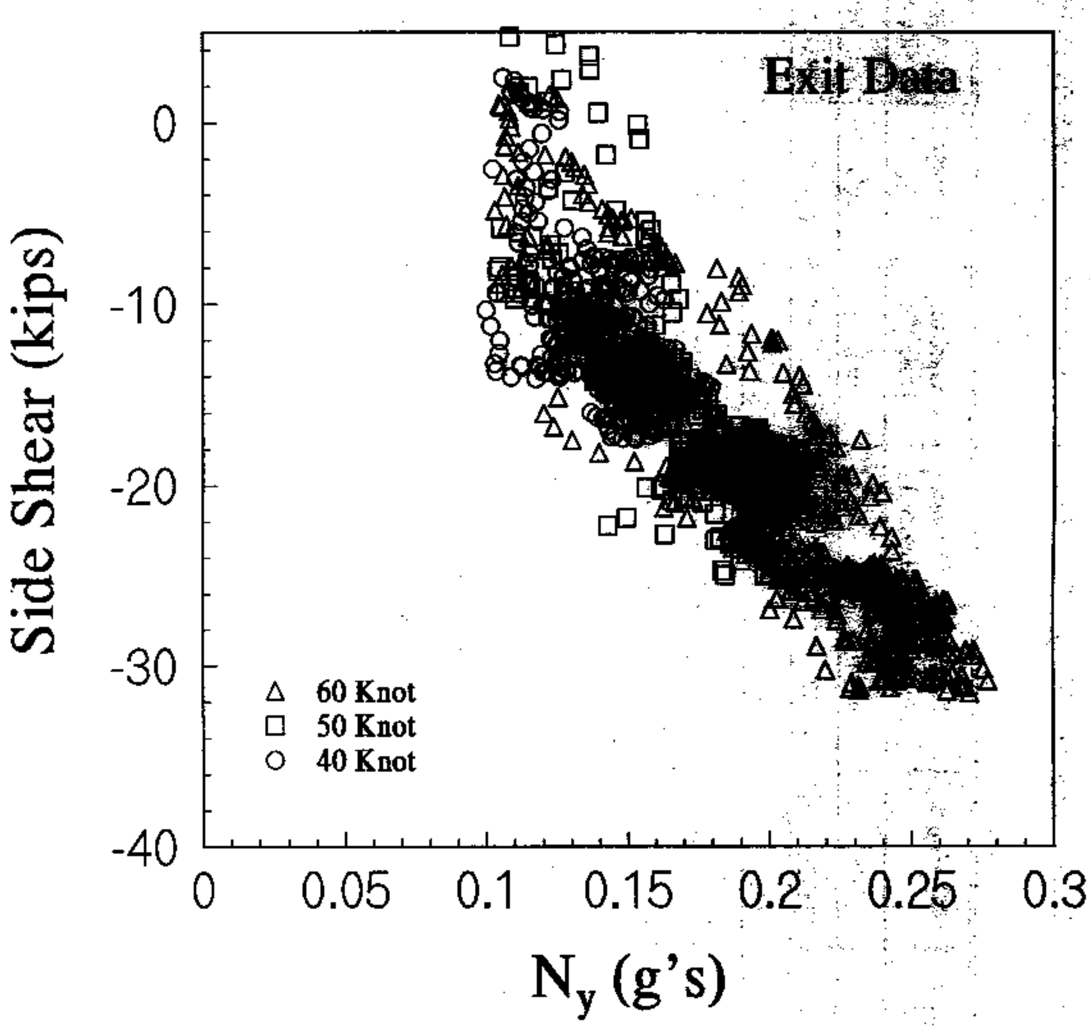


FIGURE 41. CORRELATION IN TIME OF SIDE SHEAR AND LATERAL ACCELERATION

TABLE 3. TABLE OF SPECIFIC EVENT PARAMETERS FOR THE RUNWAY EXIT EVENTS

Event	Runway	AC Weight	Time Interval	Distance Interval	Average Ground V	Average N_y	Average Side Shear	Max Vert. Shear
		(lbs)	(sec)	(ft)	(mph)	(g's)	(kips)	(kips)
TST62901	IAD-30	134726	14.557	1009	46.6	0.142	18.01	64.72
TST62902	IAD-30	134326	14.394	985	46.0	0.139	16.67	65.12
TST62903	IAD-30	134026	14.361	967	45.3	0.139	15.94	62.64
TST62904	IAD-30	133726	12.566	1048	56.1	0.173	22.60	62.57
TST62905	IAD-30	133326	12.990	1088	56.3	0.171	21.91	65.75
TST62906	IAD-30	132926	11.750	985	56.4	0.176	22.34	64.91
TST62907	IAD-30	132326	11.881	1163	65.8	0.207	26.65	63.31
TST62908	IAD-30	131726	11.554	1104	64.2	0.202	26.20	63.65
TST62909	IAD-30	131326	12.435	1210	65.3	0.202	26.10	62.65

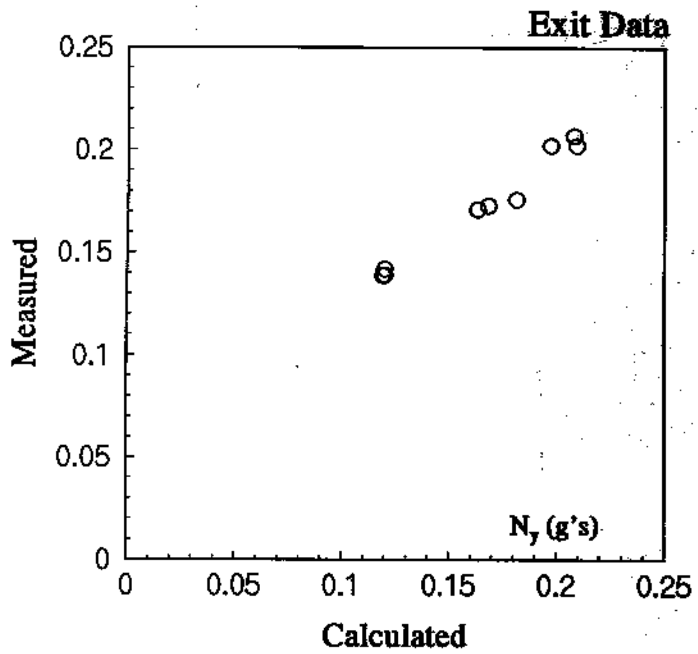


FIGURE 42. COMPARISON OF MEASURED AND CALCULATED AVERAGE LATERAL ACCELERATION

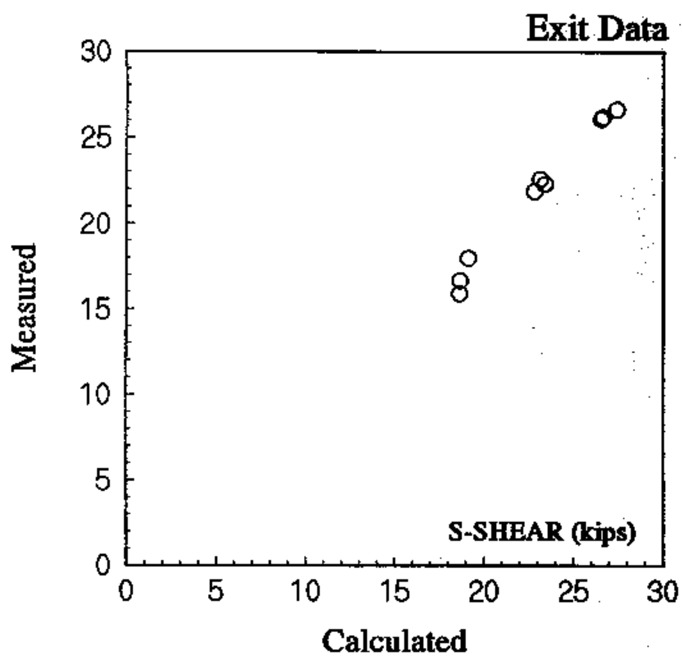


FIGURE 43. COMPARISON OF MEASURED AND CALCULATED AVERAGE SIDE SHEAR

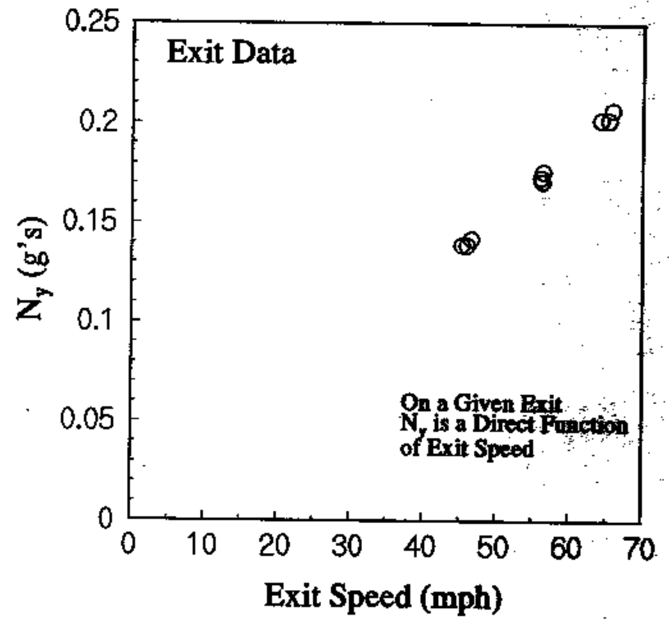


FIGURE 44. CORRELATION PLOT OF EXIT GROUND SPEED AND LATERAL ACCELERATION

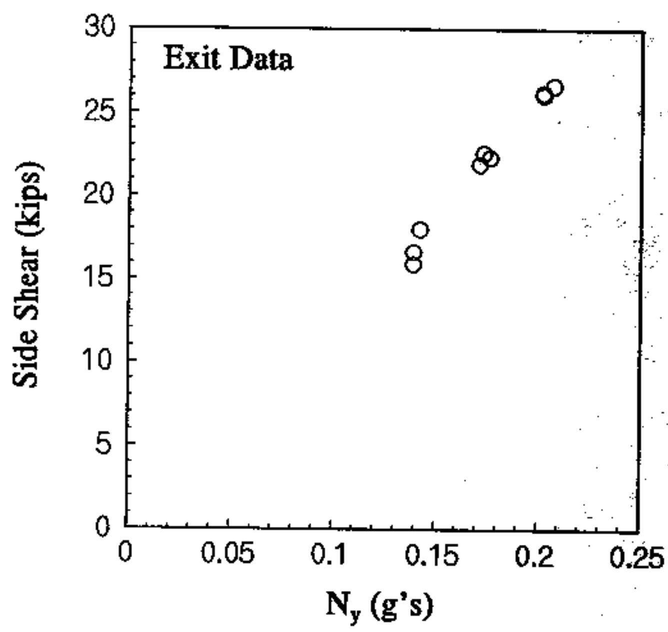


FIGURE 45. CORRELATION PLOT OF SIDE SHEAR AND LATERAL ACCELERATION

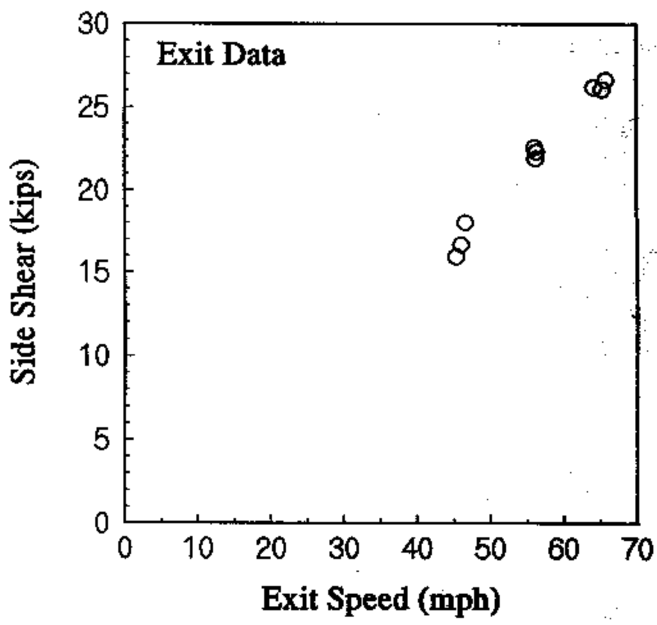


FIGURE 46. CORRELATION PLOT OF SIDE SHEAR AND EXIT GROUND SPEED

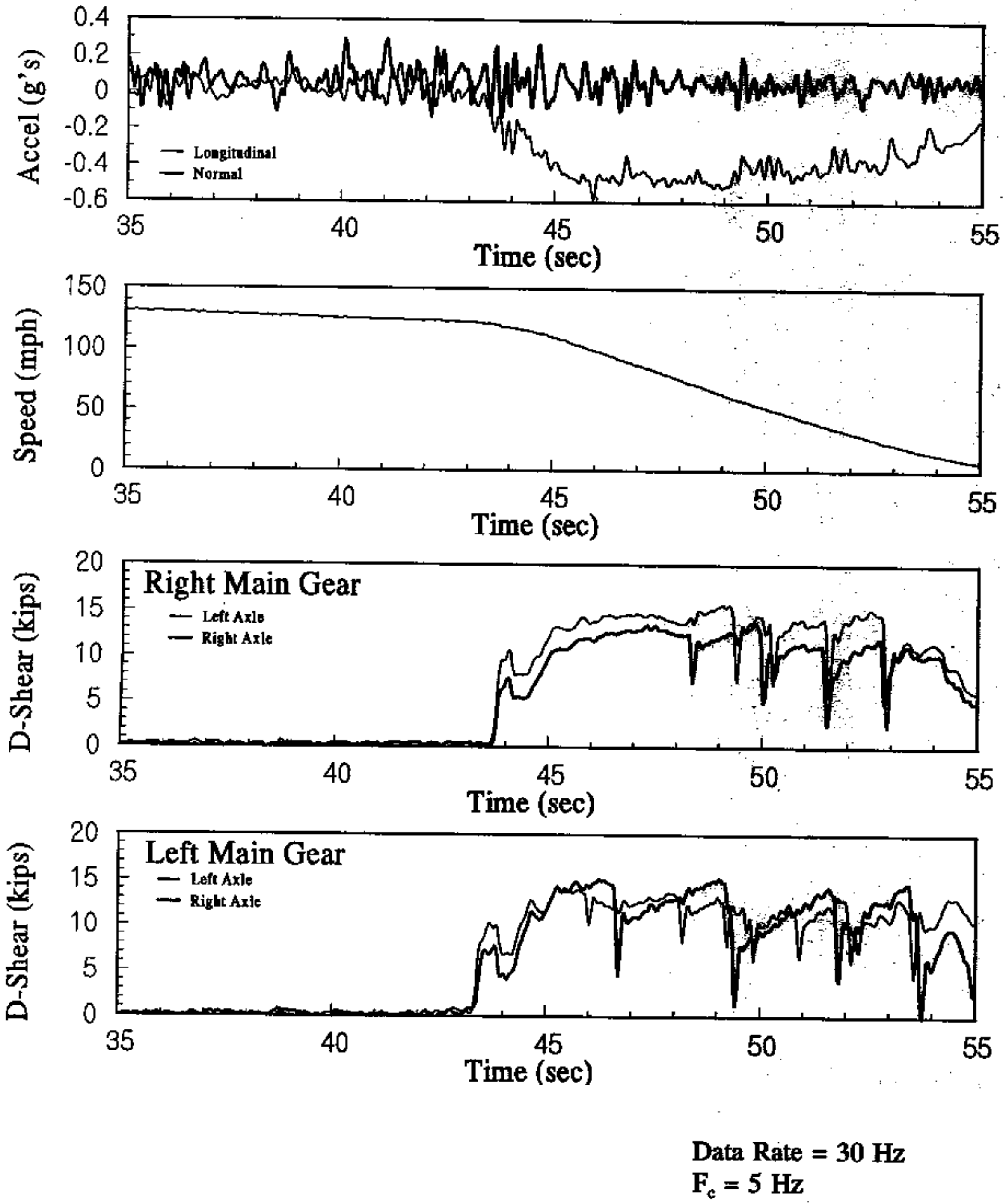
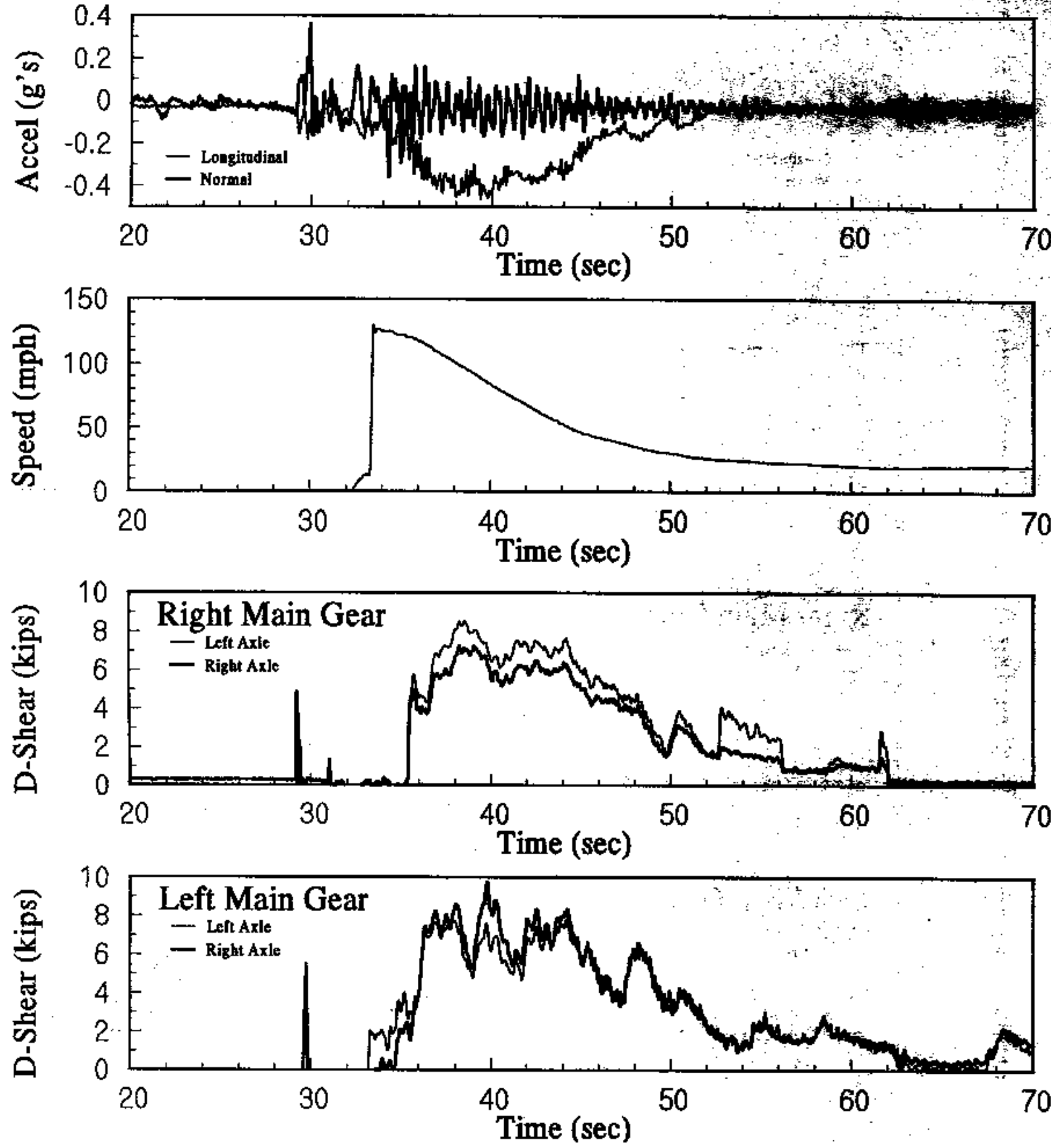


FIGURE 47. MULTIPLE TIME TRACE DATA PLOT OF A HEAVY BRAKING EVENT



Data Rate = 30 Hz
F_c = 5 Hz

FIGURE 48. MULTIPLE TIME TRACE DATA PLOT OF A NORMAL BRAKING EVENT

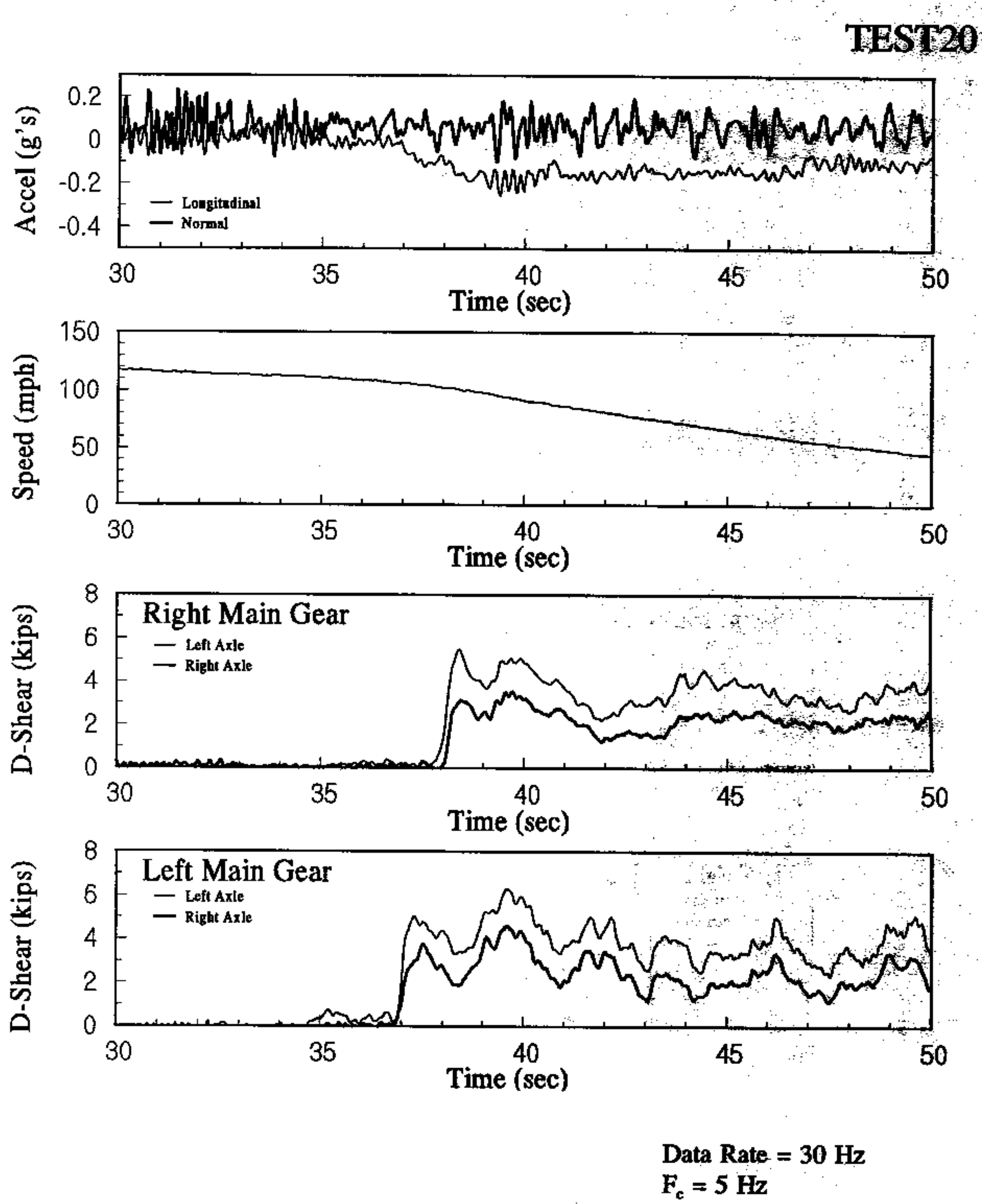


FIGURE 49. MULTIPLE TIME TRACE DATA PLOT OF A LIGHT BRAKING EVENT

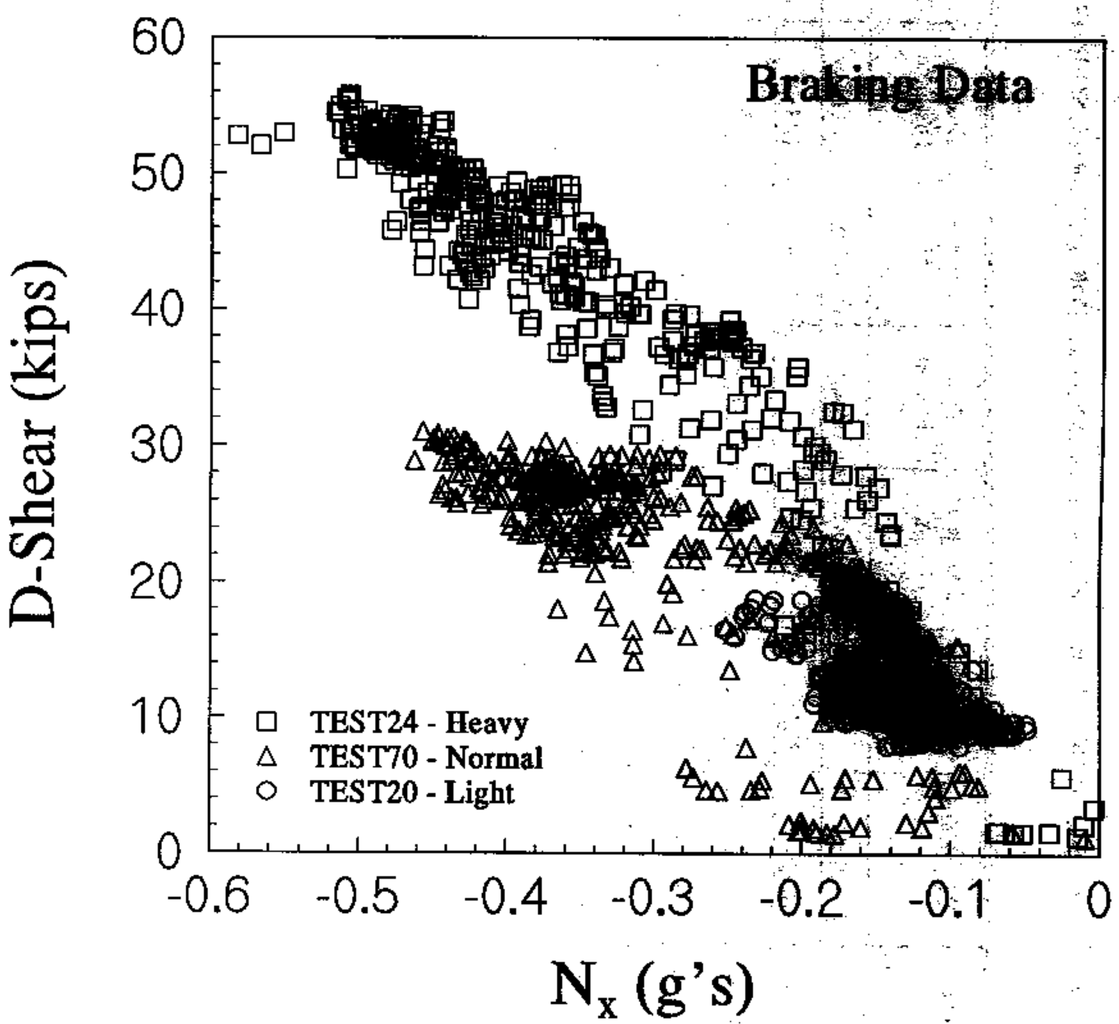


FIGURE 50. CORRELATION IN TIME OF DRAG SHEAR AND LONGITUDINAL ACCELERATION

TABLE 4. TABLE OF SPECIFIC EVENT PARAMETERS FOR THE BRAKING EVENTS

Event	Runway	AC Weight	Start Speed	Change in Ground Speed	Time Interval	Average N_x	Braking Distance	Average Drag Shear	Max Brake Pres.
		(lbs)	(mph)	(mph)	(sec)	(g's)	(ft)	(kips)	(psi)
TEST24	ACY-31	116726	122.6	114.7	11.88	-0.369	1127	42.50	2888
TEST20	ACY-31	118226	102.6	53.5	11.00	-0.143	1211	11.77	853
TEST66	ACY-13	124826	107.1	81.1	21.35	-0.135	2190	15.10	1071
TEST70	ACY-31	119226	125.3	93.8	15.01	-0.280	1628	21.84	1742
TST70701	JFK-131	137350	115.0	103.2	29.99	-0.085	2663	15.70	939
TST71001	LGA-22	138600	81.7	44.4	7.15	-0.214	616	37.70	2271

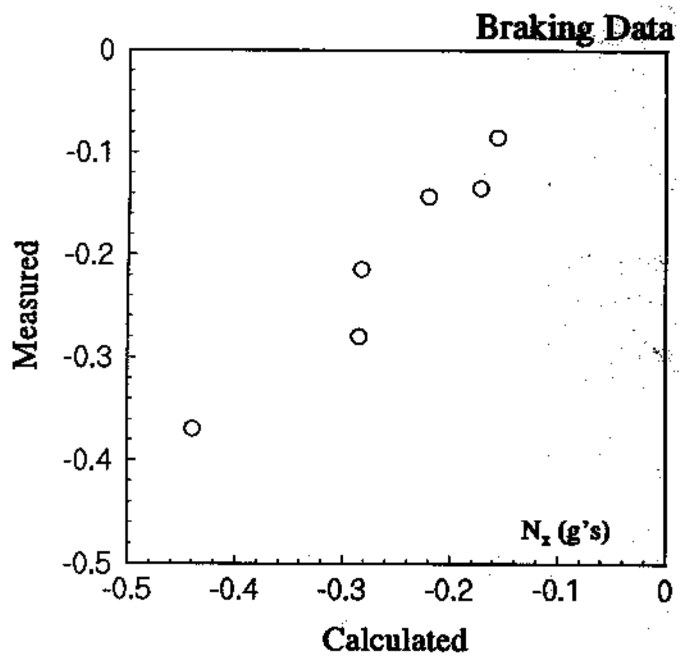


FIGURE 51. COMPARISON OF MEASURED AND CALCULATED AVERAGE LONGITUDINAL ACCELERATION

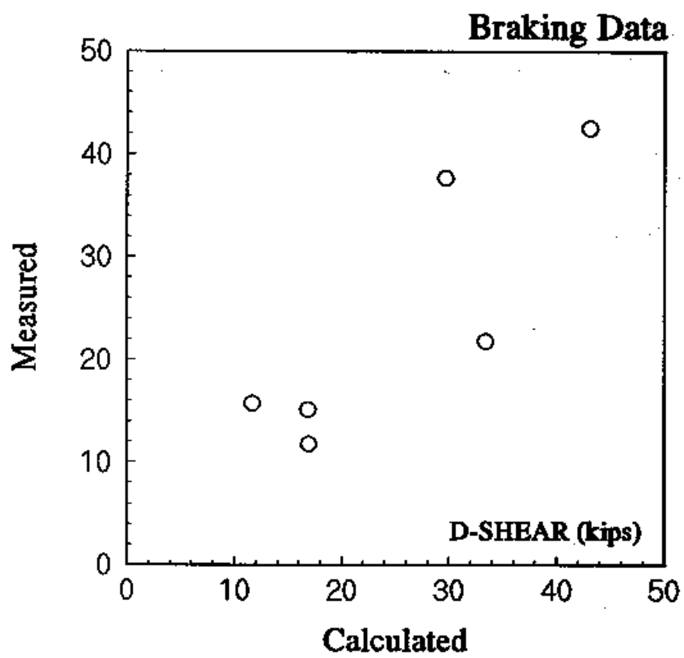


FIGURE 52. COMPARISON OF MEASURED AND CALCULATED AVERAGE DRAG SHEAR

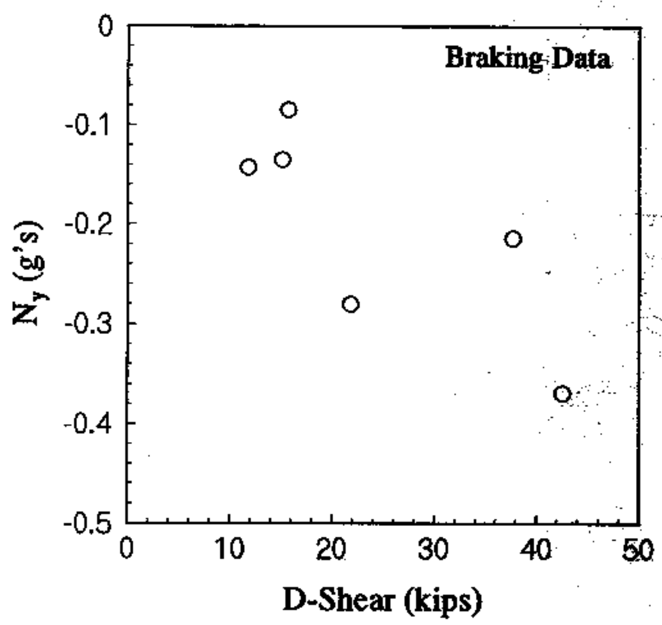
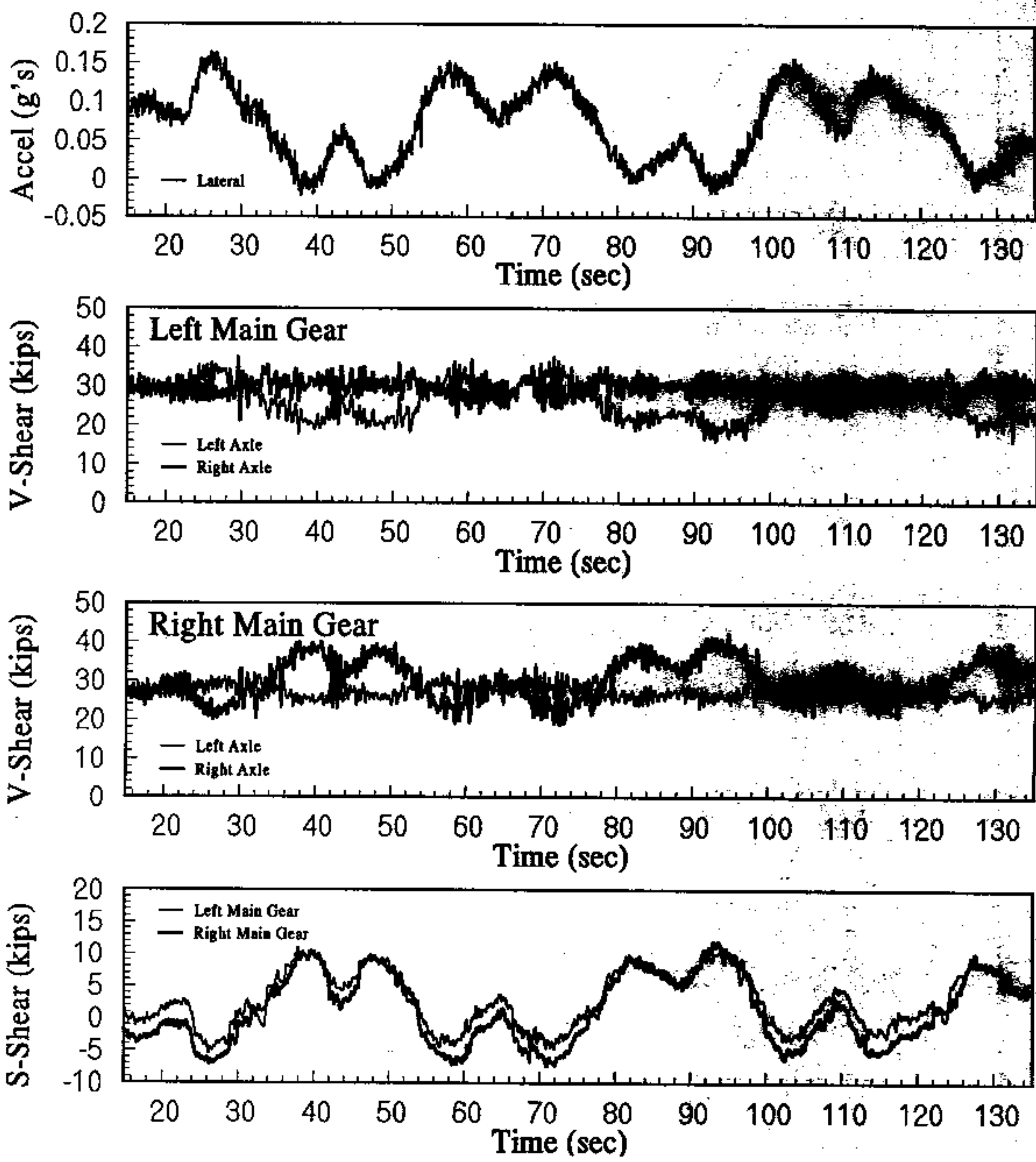
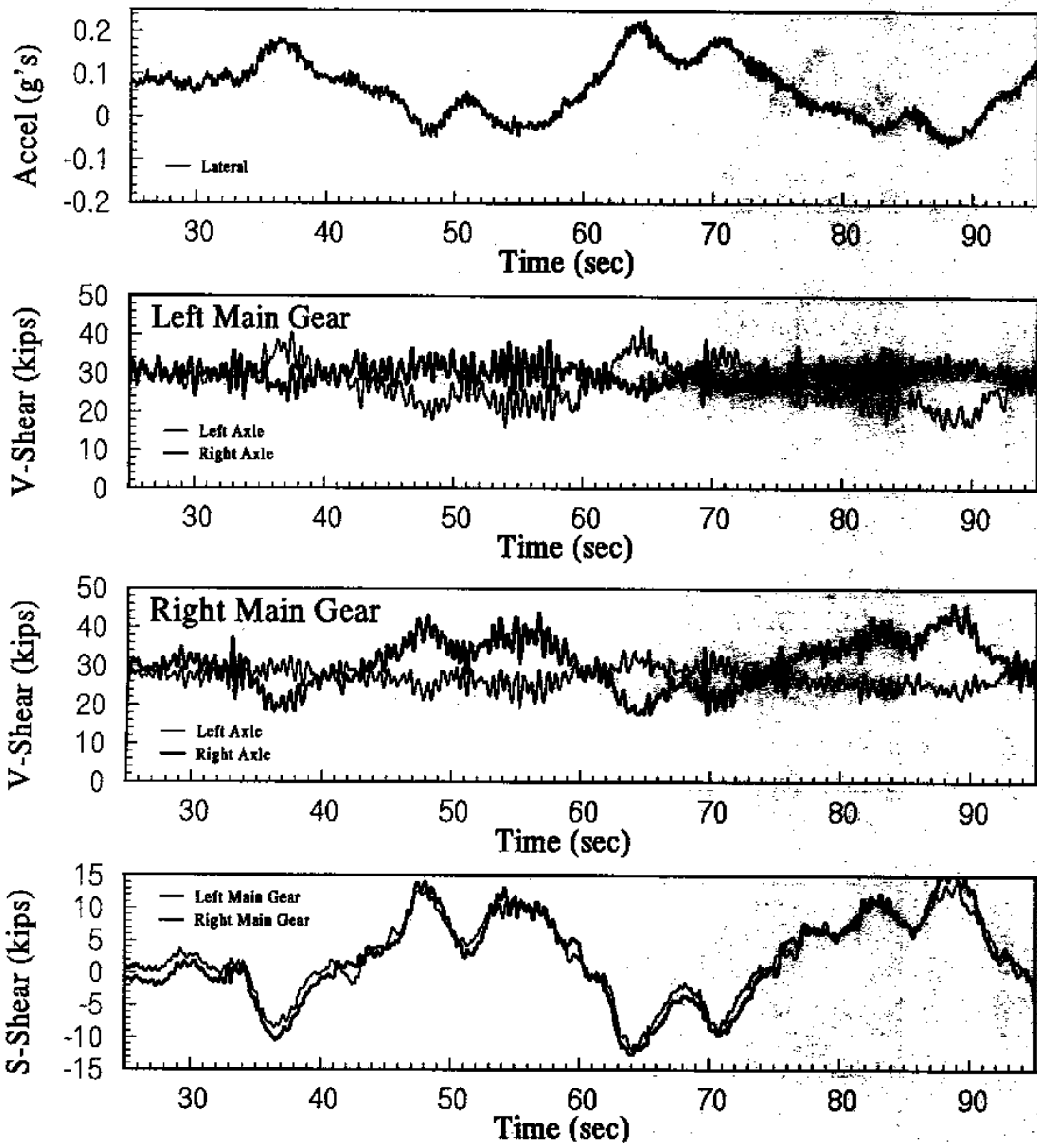


FIGURE 53. CORRELATION PLOT OF AVERAGE DRAG SHEAR AND LONGITUDINAL ACCELERATION



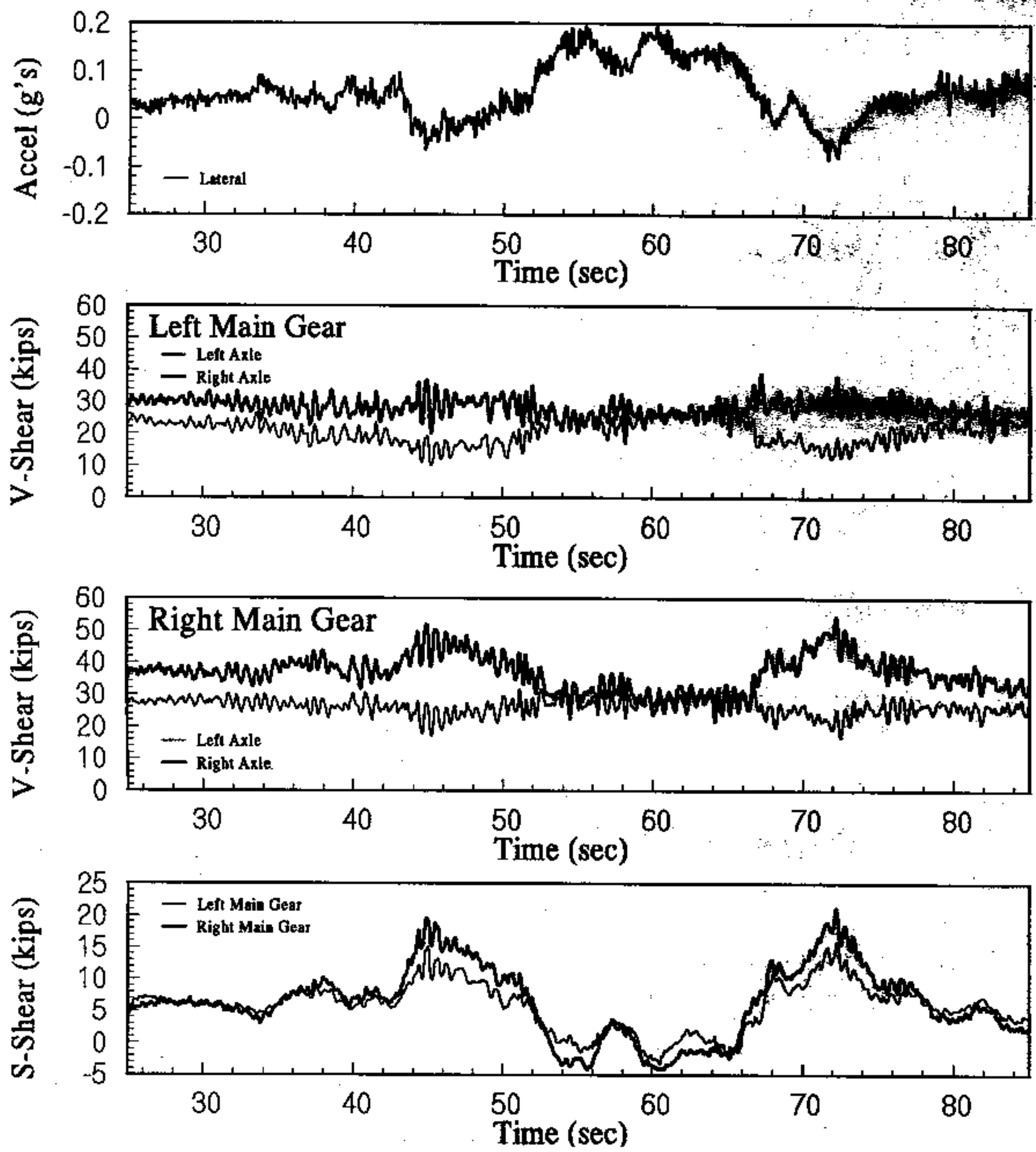
Data Rate = 30 Hz
F_c = 5 Hz

FIGURE 54. MULTIPLE TIME TRACE DATA PLOT OF A TYPICAL S-TURN AT 40 KNOTS



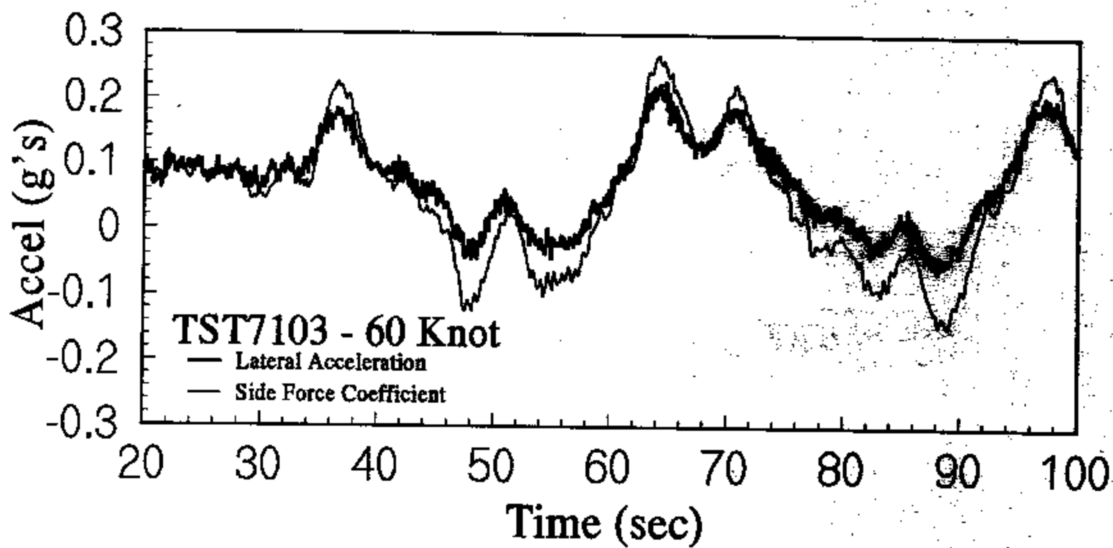
Data Rate = 30 Hz
F_c = 5 Hz

FIGURE 55. MULTIPLE TIME TRACE DATA PLOT OF A TYPICAL S-TURN AT 60 KNOTS

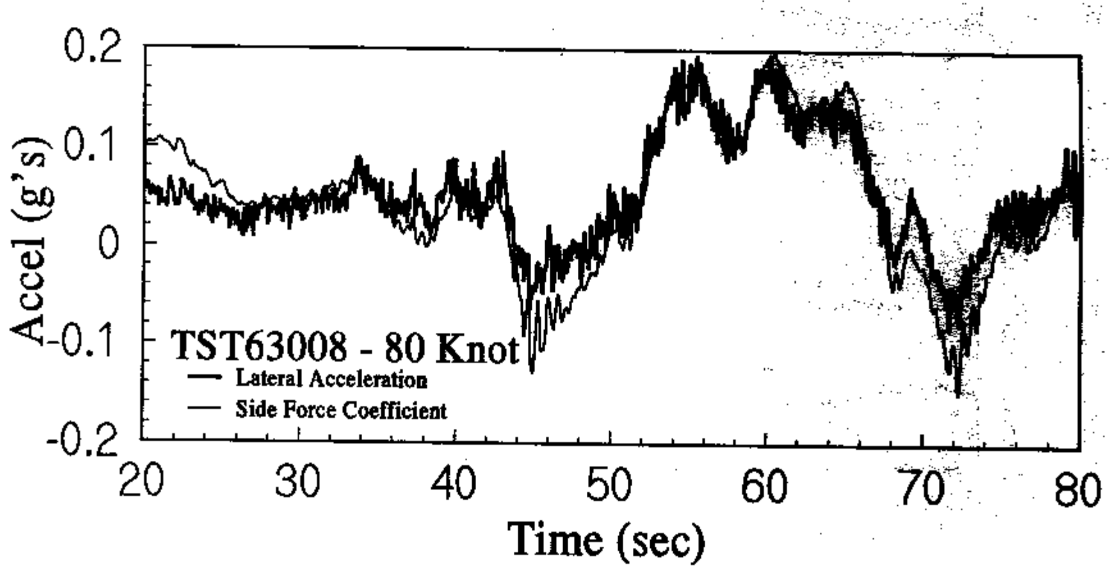


Data Rate = 30 Hz
F_c = 5 Hz

FIGURE 56. MULTIPLE TIME TRACE DATA PLOT OF A TYPICAL S-TURN AT 80 KNOTS

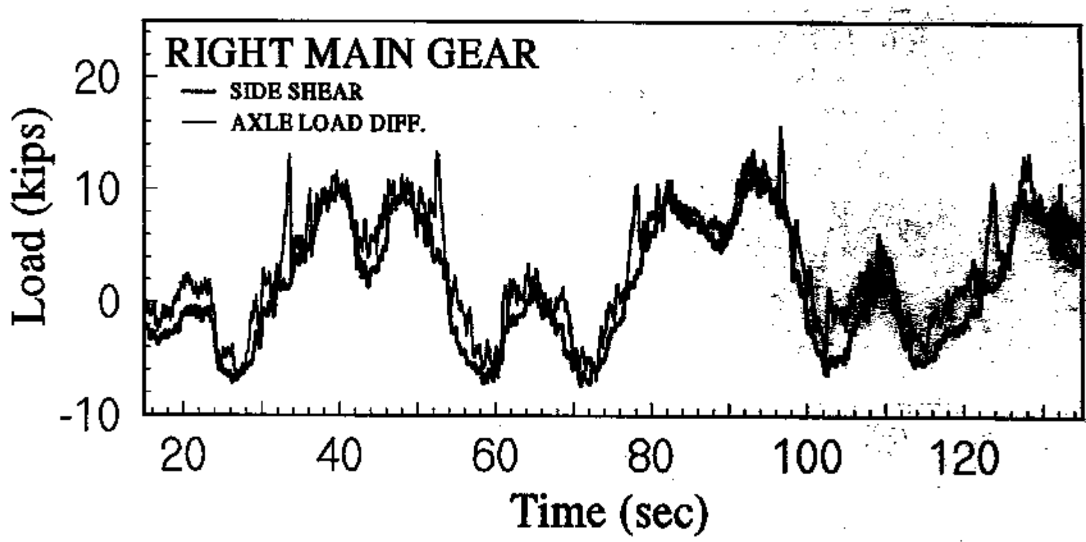


GRAPH 57(a)

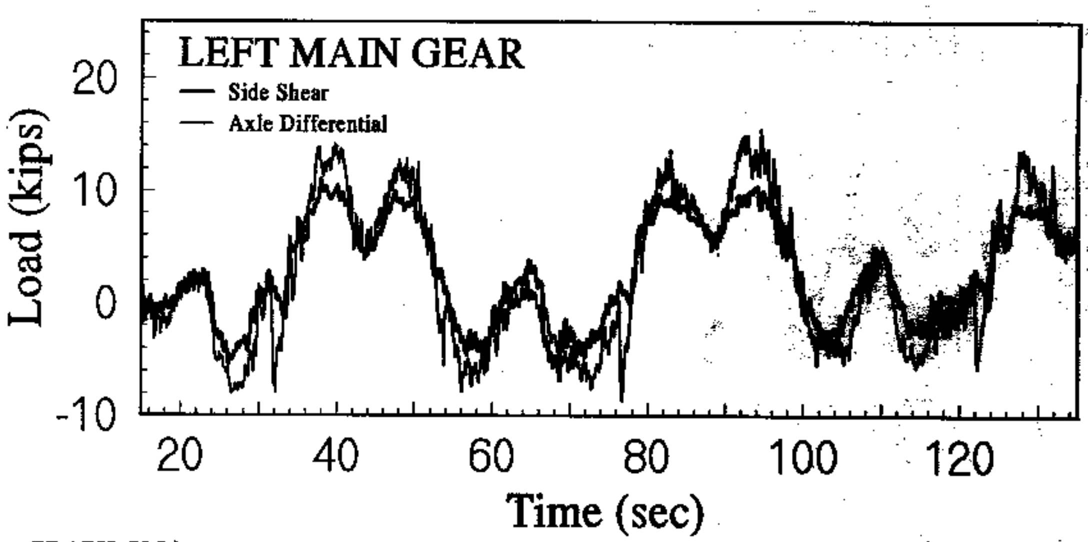


GRAPH 57(b)

FIGURE 57. COMPARISON IN TIME OF SIDE FORCE COEFFICIENT AND LATERAL ACCELERATION FOR (a.) TST7103 AND (b.) TST63008

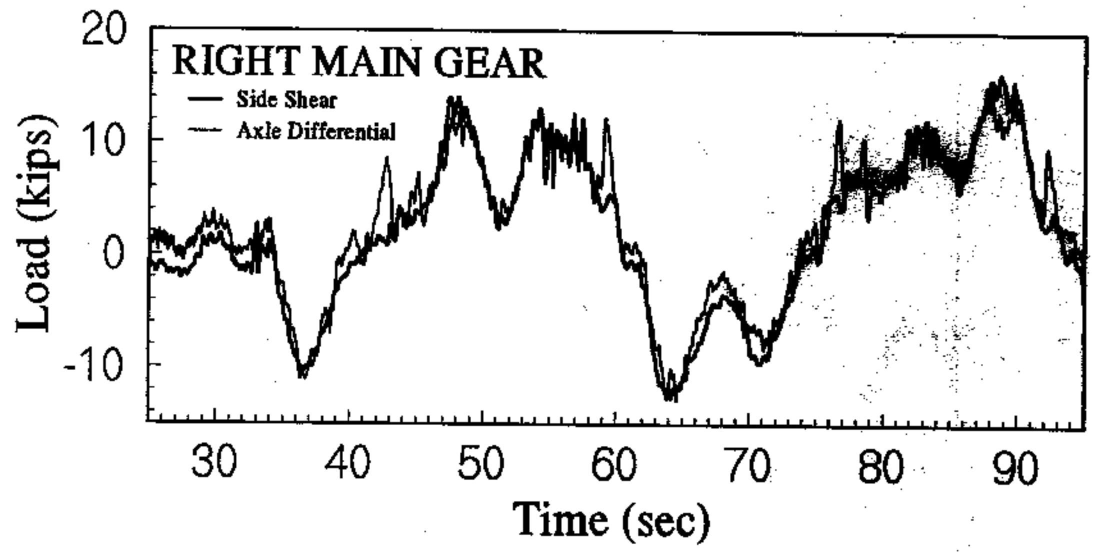


GRAPH 58(a)

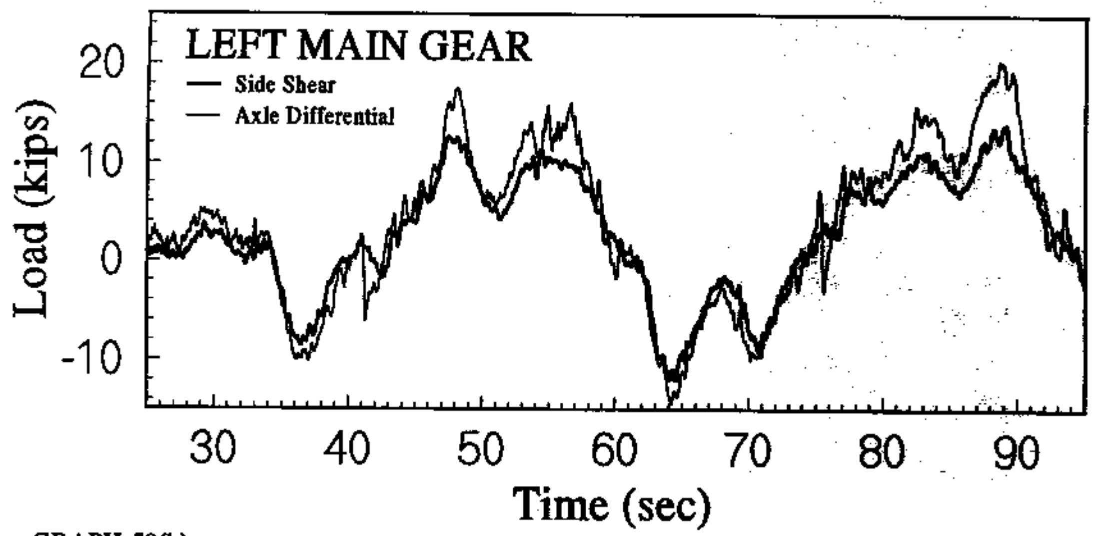


GRAPH 58(b)

FIGURE 58. SIDE SHEAR AND AXLE DIFFERENTIAL LOAD PLOTTED IN TIME FOR THE TWO MAIN LANDING GEAR; 40-KNOT S-TURN

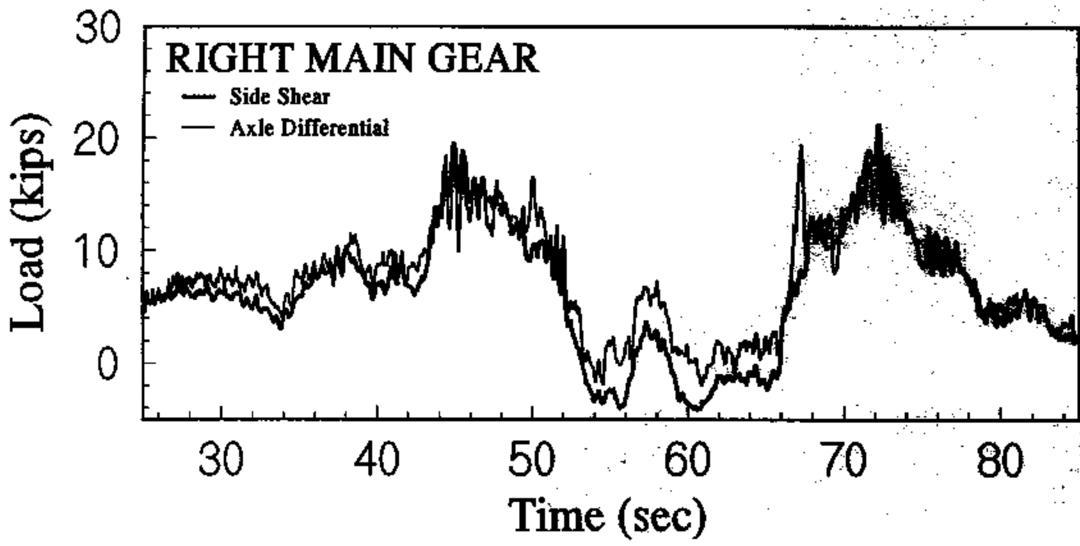


GRAPH 59(a)

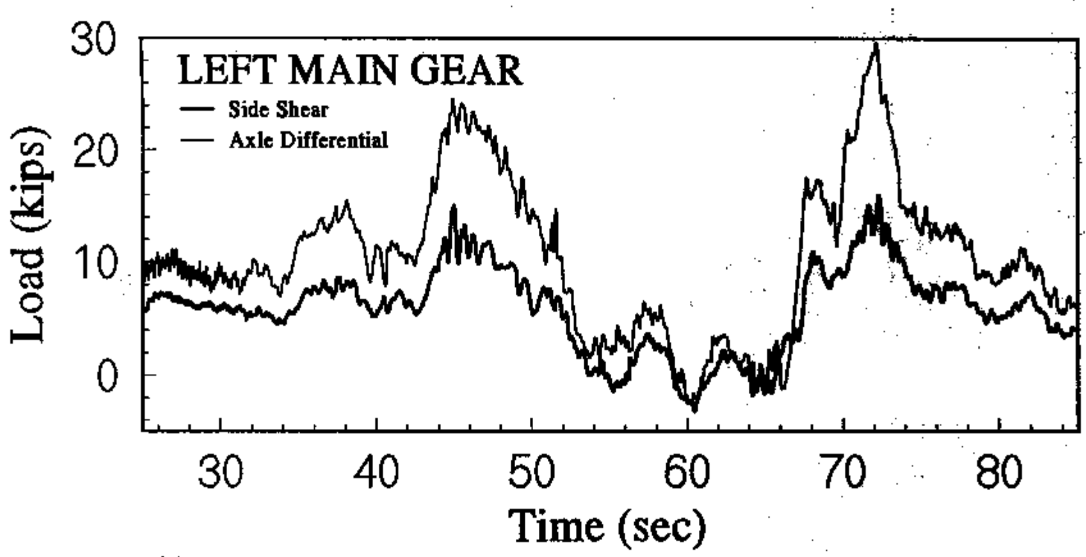


GRAPH 59(b)

FIGURE 59. SIDE SHEAR AND AXLE DIFFERENTIAL LOAD PLOTTED IN TIME FOR THE TWO MAIN LANDING GEAR; 60-KNOT S-TURN



GRAPH 60(a)



GRAPH 60(b)

FIGURE 60. SIDE SHEAR AND AXLE DIFFERENTIAL LOAD PLOTTED IN TIME FOR THE TWO MAIN LANDING GEAR; 80-KNOT S-TURN

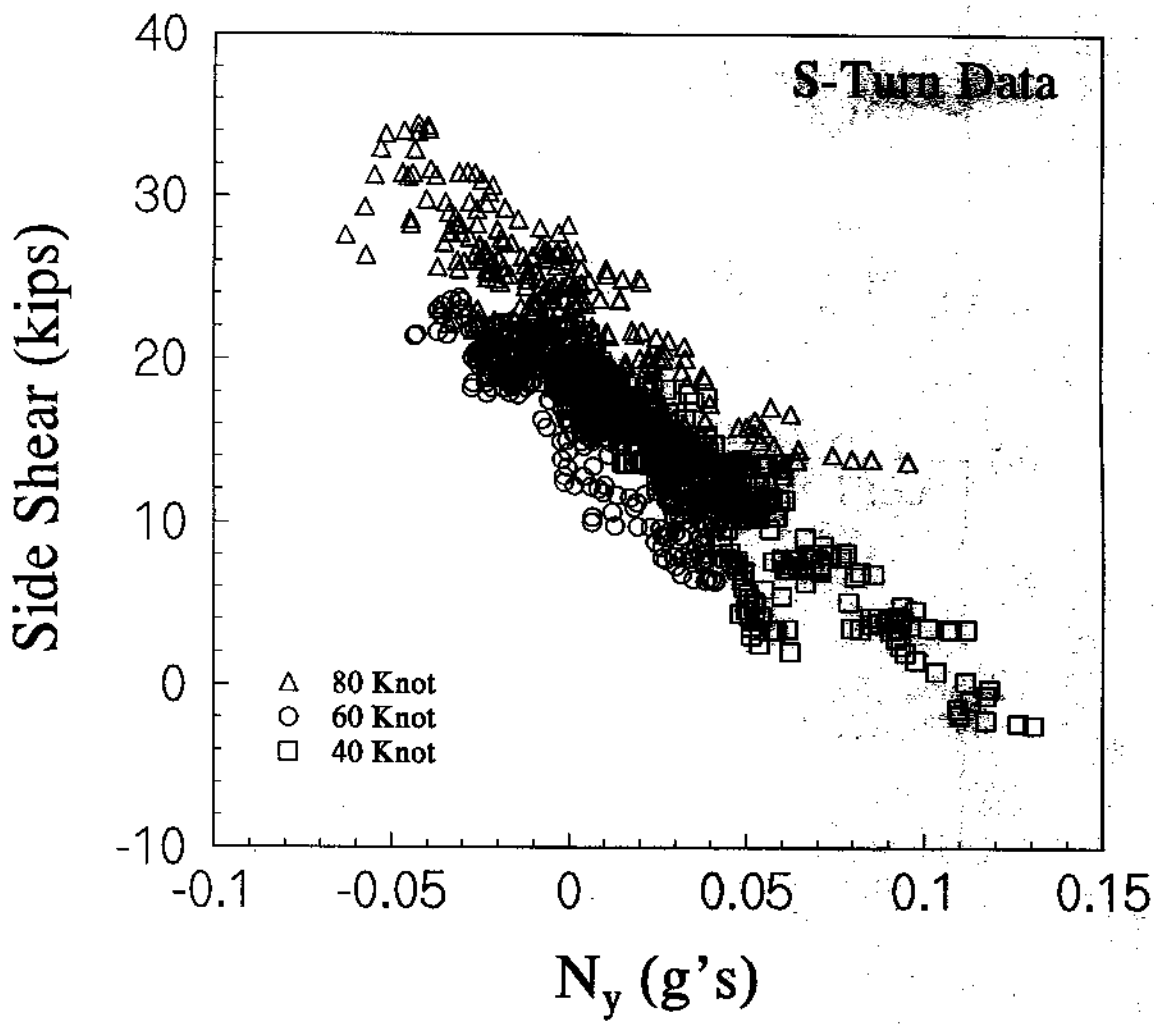


FIGURE 61. CORRELATION IN TIME OF SIDE SHEAR AND LATERAL ACCELERATION

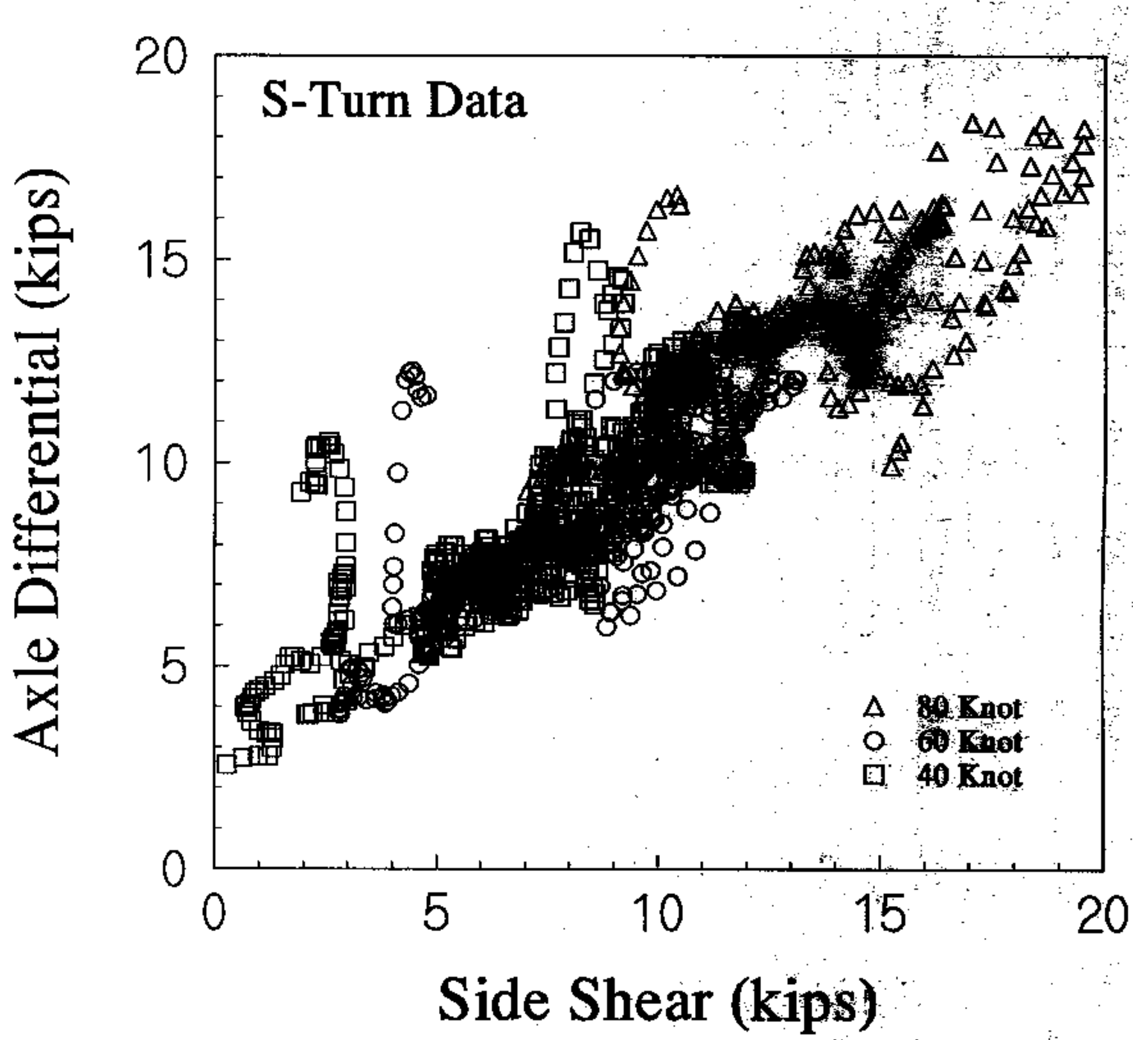


FIGURE 62. CORRELATION IN TIME OF SIDE SHEAR AND AXLE DIFFERENTIAL LOAD

TABLE 5. TABLE OF SPECIFIC EVENT PARAMETERS FOR THE S-TURN EVENTS

Event	Runway	AC Weight	Start Speed	Time Interval	Average N_y	Ave. Side Shear LMG / RMG	Ave. Diff. Shear LMG / RMG	Maximum Diff. Shear
		(lbs)	(kts)	(sec)	(g's)	(kips)	(kips)	(kips)
TST63008	ACY-31	126426	80	7.311	0.0472	3.93 / 7.58	11.11 / 5.53	16.61
TST7101	ACY-31	131126	80	7.931	0.0693	8.39 / 9.66	11.90 / 10.30	19.32
TST7102	ACY-13	130826	80	8.649	0.0609	7.48 / 7.69	8.66 / 8.14	16.76
TST7103	ACY-31	130326	60	7.931	0.0771	8.15 / 8.18	10.93 / 8.51	16.06
TST7104	ACY-13	129526	60	7.474	0.0658	6.93 / 5.68	8.15 / 5.92	16.71
TST7105	ACY-31	129226	60	8.258	0.0657	7.13 / 8.62	13.48 / 9.08	23.67
TST7111	ACY-31	124126	40	22.292	0.0611	7.29 / 7.03	8.72 / 8.33	15.66
TST7112	ACY-13	123726	40	22.357	0.0589	5.46 / 3.38	5.19 / 4.63	10.62
TST7113	ACY-31	123226	40	21.607	0.0264	2.02 / 2.68	5.52 / 4.25	14.17

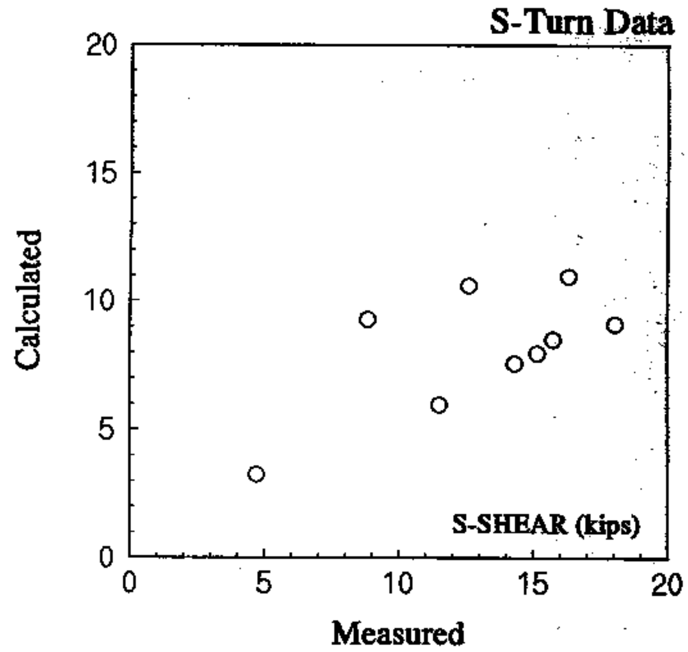


FIGURE 63. COMPARISON OF MEASURED AND CALCULATED AVERAGE SIDE SHEAR

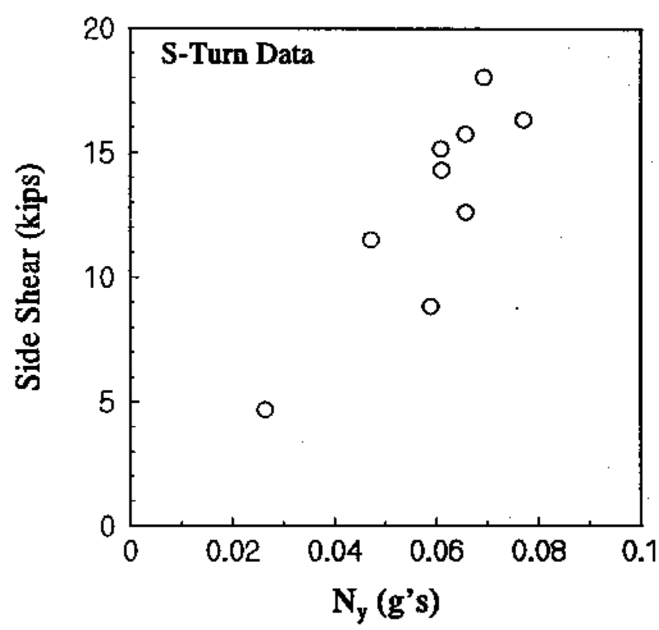


FIGURE 64. CORRELATION PLOT OF SIDE SHEAR AND LATERAL ACCELERATION

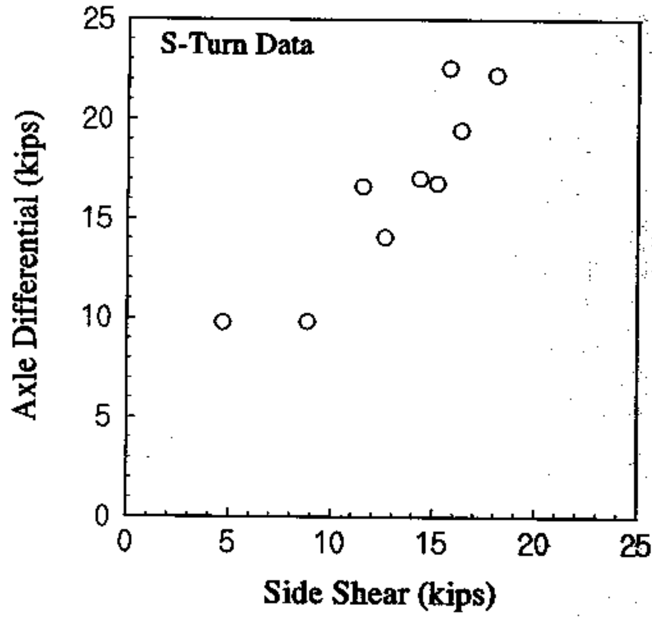


FIGURE 65. CORRELATION PLOT OF SIDE SHEAR AND AXLE DIFFERENTIAL LOAD

TEST32

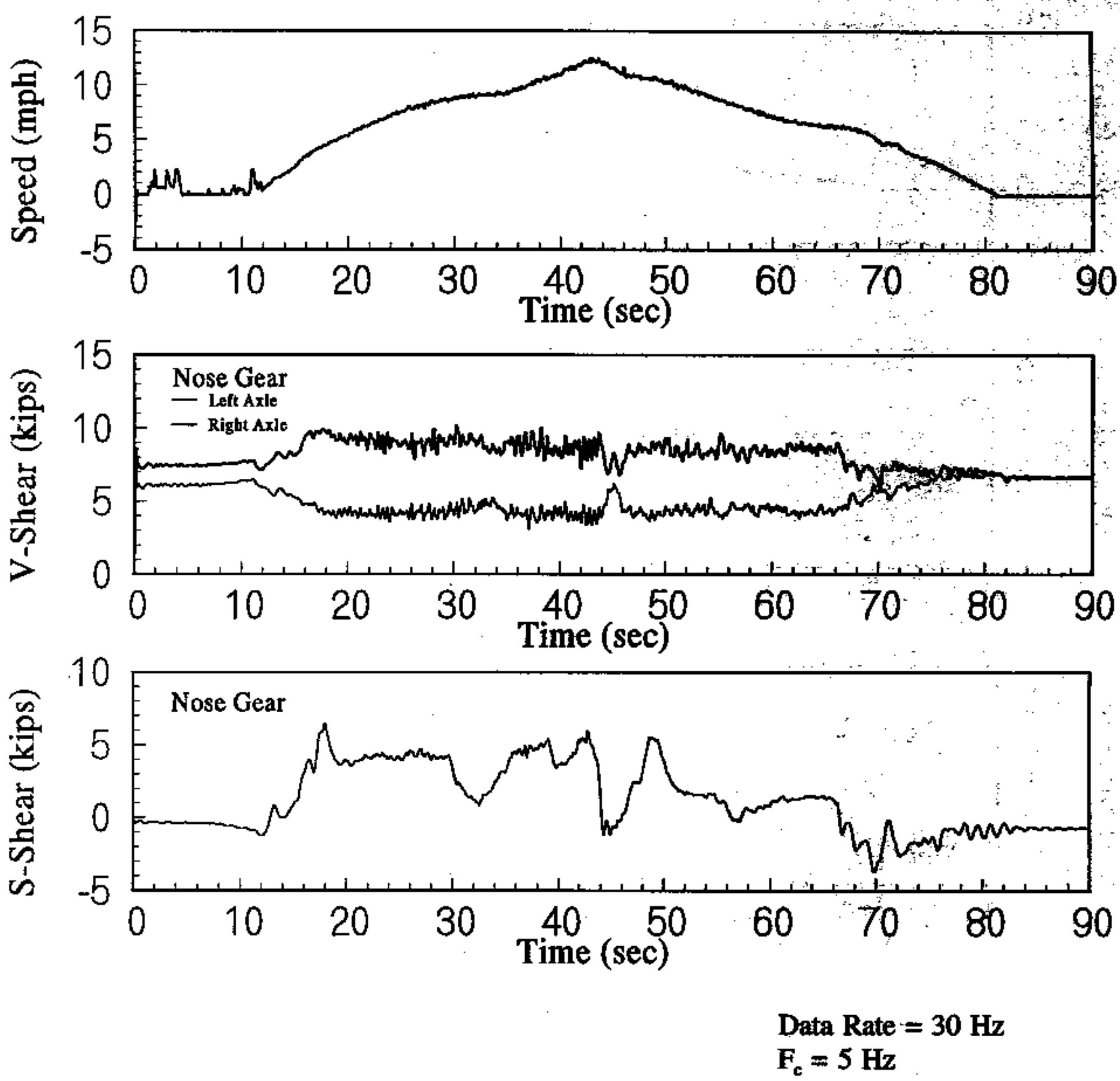
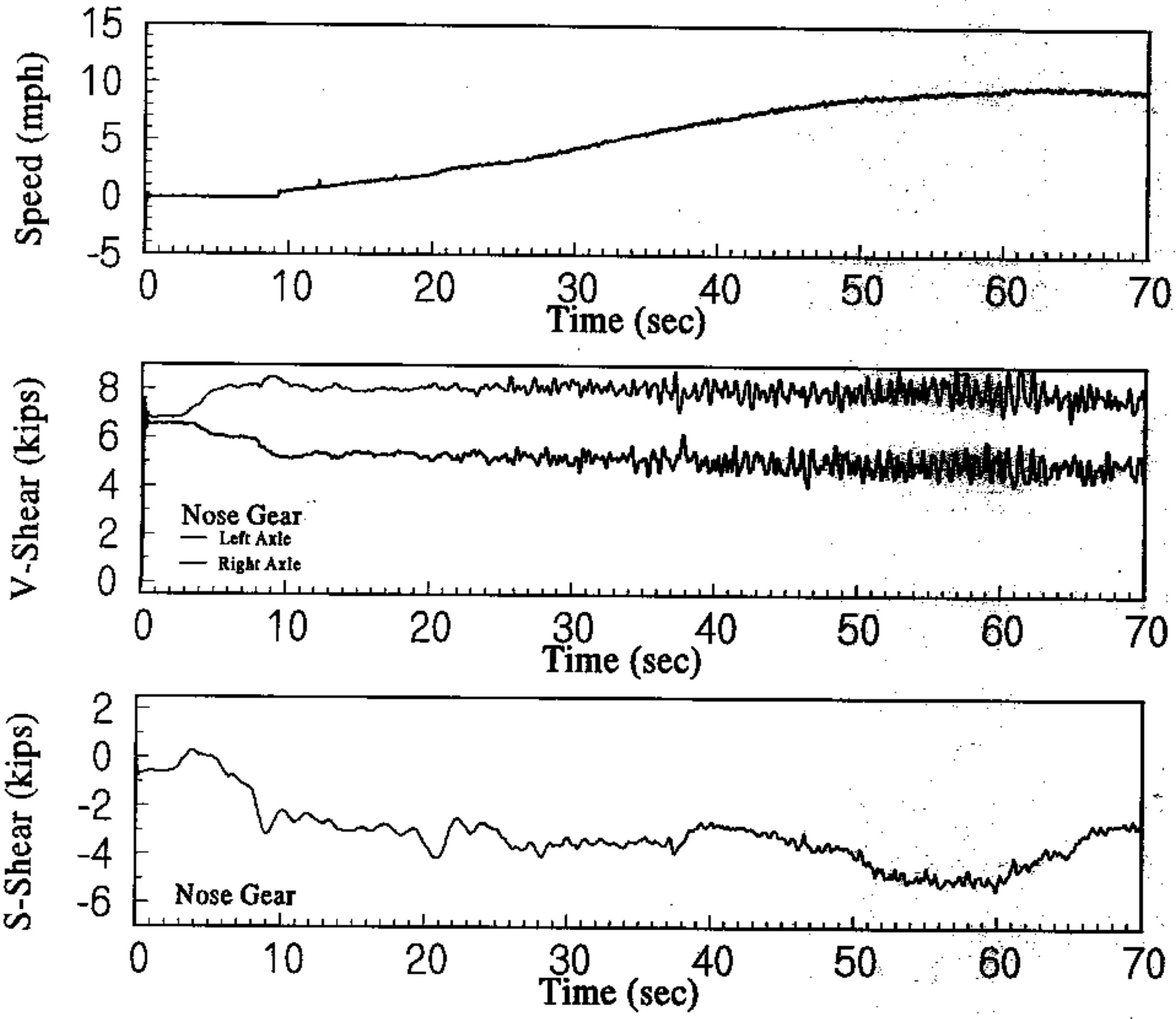


FIGURE 66. MULTIPLE TIME TRACE DATA PLOT OF A TYPICAL MINIMUM-RADIUS TURN; CCW

TEST34



Data Rate = 30 Hz
F_c = 5 Hz

FIGURE 67. MULTIPLE TIME TRACE DATA PLOT OF A TYPICAL MINIMUM-RADIUS TURN; CW

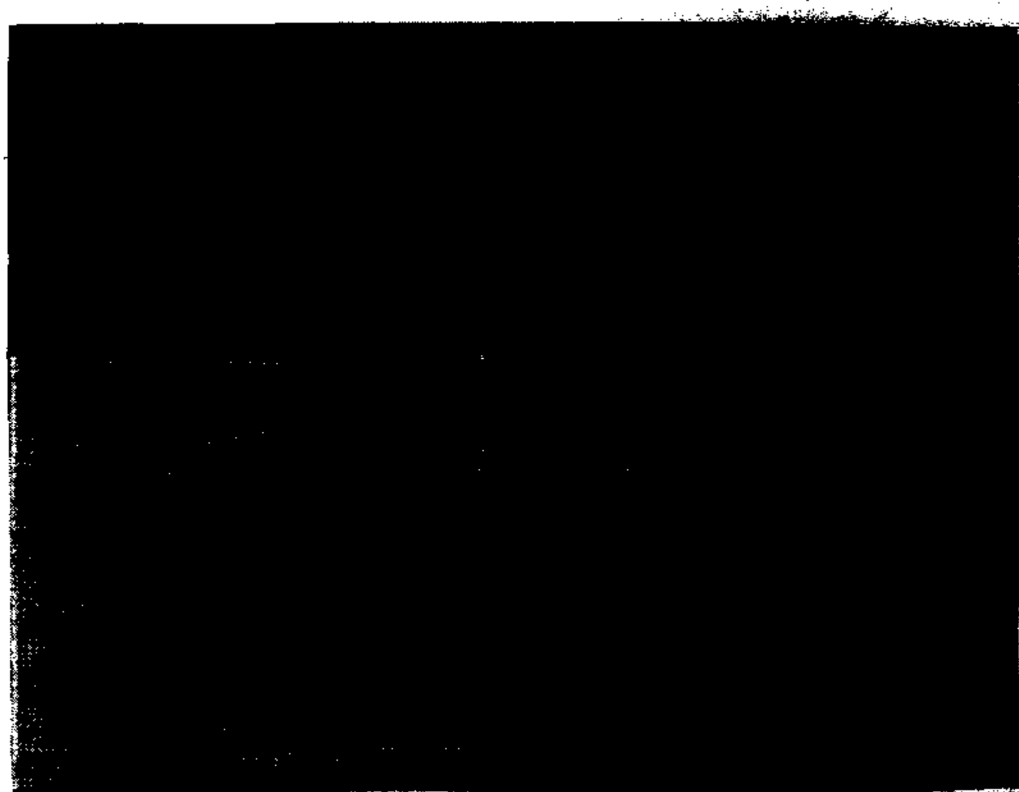


FIGURE 68. PHOTO OF NOSE GEAR DURING MINIMUM-RADIUS TURN

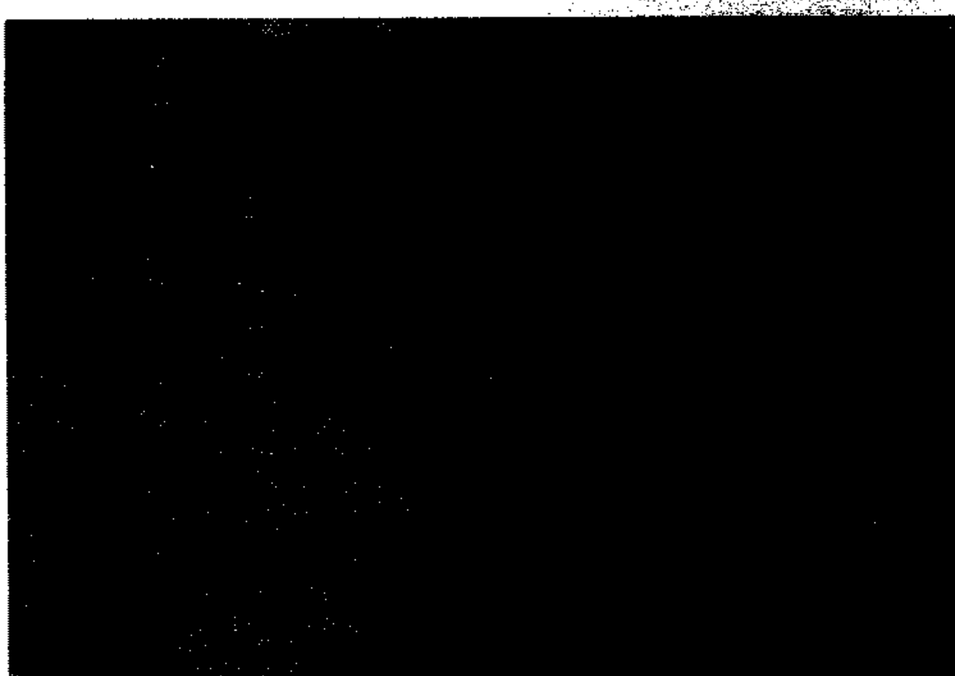
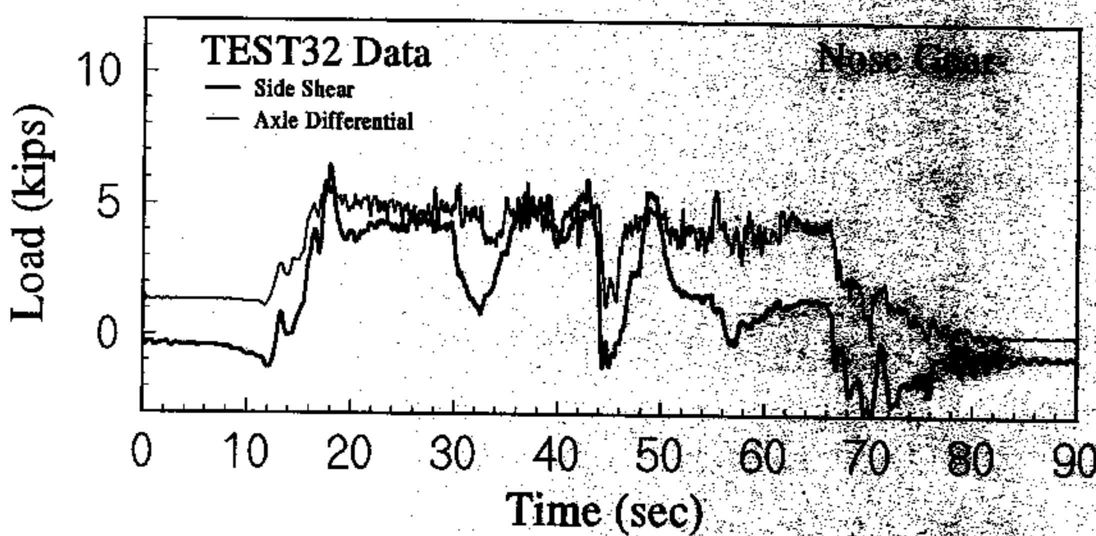
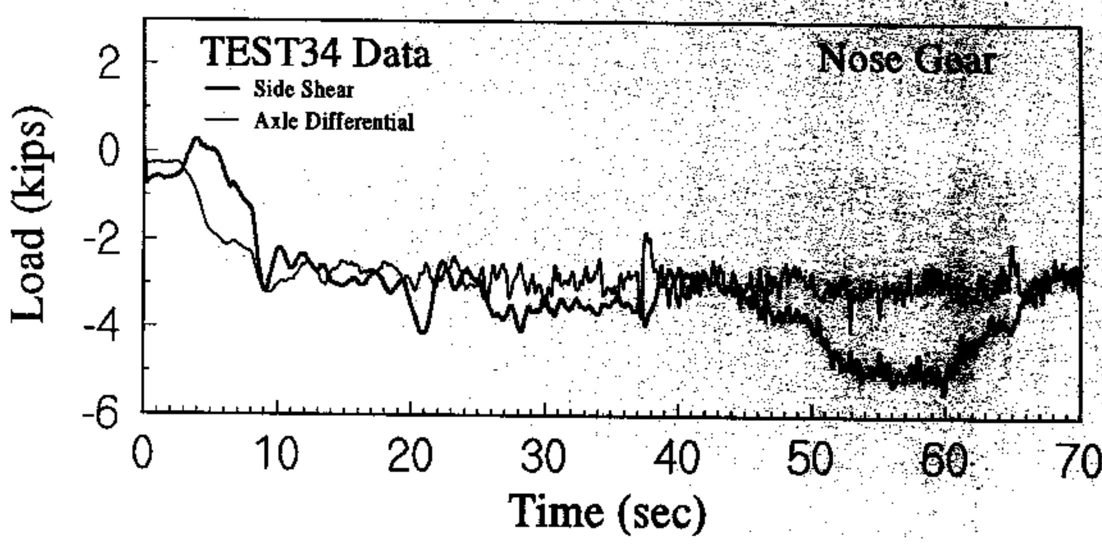


FIGURE 69. PHOTO OF RUBBER TIRE TRACKS DEPOSITED ON PAVEMENT



GRAPH 70(a)



GRAPH 70(b)

FIGURE 70. COMPARISON IN TIME OF SIDE SHEAR AND AXLE DIFFERENTIAL LOAD FOR (a.) TEST32 AND (b.) TEST34

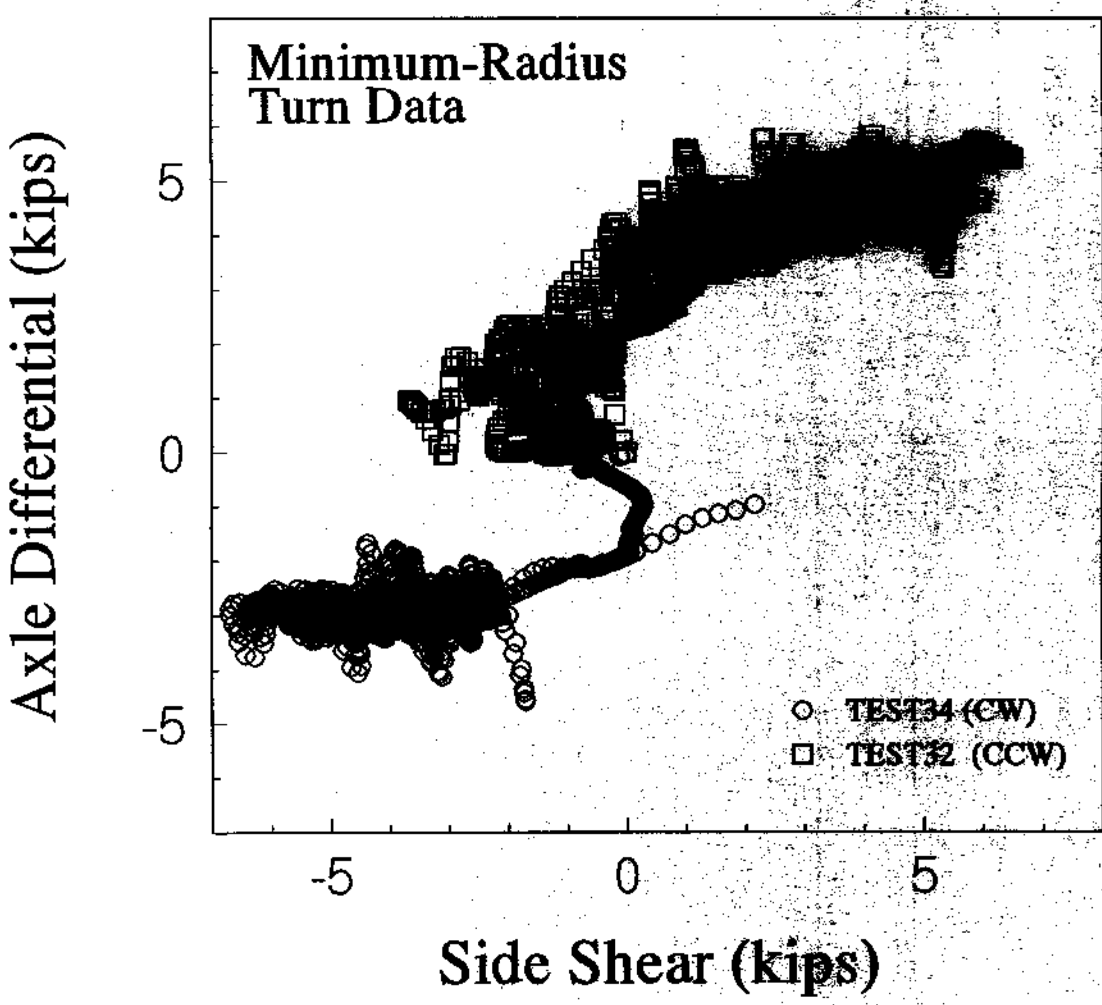


FIGURE 71. CORRELATION IN TIME OF SIDE SHEAR AND AXLE DIFFERENTIAL LOAD

TABLE 6. TABLE OF SPECIFIC EVENT PARAMETERS FOR THE MINIMUM-RADIUS TURN EVENTS

Event	Runway	AC Weight	Direction	Time Interval	Average V_{tan}	Average NG Side Shear	Average NG Diff. Shear	Maximum Diff. Shear
		(lbs)		(sec)	(mph)	(kips)	(kips)	(kips)
TST7116	ACY RMP	122526	CW	10	0.9	-1.59	-2.78	-3.08
TST7117	ACY RMP	122226	CCW	10	2.5	2.16	3.75	4.41
TEST32	ACY RMP	130126	CCW	10	7.4	4.15	4.83	5.63
TEST33	ACY RMP	129426	CCW	10	8.1	3.08	4.59	5.55
TEST34	ACY RMP	129226	CW	10	3.1	-3.38	-2.88	-3.49
TEST49	ACY RMP	120326	CW	10	7.4	-2.77	-2.98	-3.70
TEST50	ACY RMP	120226	CW	10	5.9	-2.03	-2.85	-3.53
TEST51	ACY RMP	120026	CW	10	5.1	-1.99	-3.22	-3.73

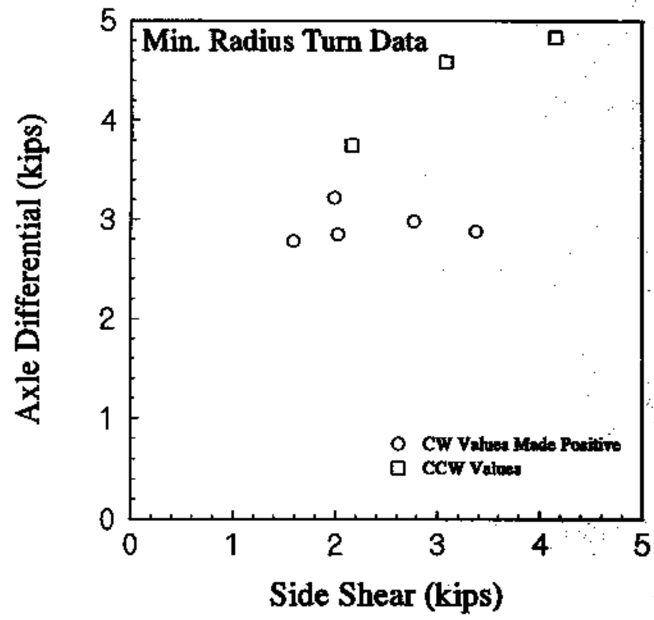


FIGURE 72. CORRELATION PLOT OF NOSE GEAR AVERAGE SIDE SHEAR AND AXLE DIFFERENTIAL LOAD

APPENDIX A

Listing of Tests

TABLE OF DATA FILES ACQUIRED FROM THE FAA B-727 N40 FLIGHT-GROUND LOADS INVESTIGATION

FLTTST29 / GND2	-	-	30		0	15	-	-	-	-	
TST62901 / GND2	06/29 18:42	IAD	49	0	0	49	30	210/8	33.1	134726	High speed exit. No reverse. CG=5.
TST62902 / GND2	06/29 18:46	IAD	61	0	0	61	30	210/8	32.7	134326	High speed exit. Seemed to take the turn in "bites". No reverse. CG=5
TST62903 / GND2	06/29 18:51	IAD	61	0	0	61	30	200/9	32.4	134026	High speed exit. No reverse. CG=5
TST62904 / GND2	06/29 18:57	IAD	61	0	0	61	30	200/9	32.1	133726	High speed exit. Very Smooth. No reverse. CG=5
TST62905 / GND2	06/29 19:02	IAD	61	0	0	61	30	200/8	31.7	133326	High speed exit. No reverse. CG=5
TST62906 / GND2	06/29 19:04	IAD	61	0	0	61	30	200/8	31.3	132926	High speed exit. No reverse. CG=5
TST62907 / GND2	06/29 19:16	IAD	61	0	0	61	30	200/9	30.7	132326	High speed exit. Felt Smooth. No reverse. CG=5
TST62908 / GND2	06/29 19:28	IAD	61	0	0	61	30	200/9	30.1	131726	High speed exit. No reverse. CG=5
TST62909 / GND2	06/29 19:35	IAD	61	0	0	61	30	200/9	29.7	131326	High speed exit. No reverse. CG=5
TST62910 / GND2	06/29 19:45	IAD	91	[redacted]	0	6	30	200/10	29.3	130926	T/O to cool tires. Recording started late [illegible] 10611 On video
TST63001 / GND2	06/30 14:45	ACY	121	0	0	121	31	170/10	28.9	130526	80 knot S-Turns. Right side 13/31. R-L,L-R. CG=6.5
TST63002 / GND2	06/30 14:48	ACY	182	0	0	182	13	170/10	28.8	130426	80 knot S-Turns, Back Side 13/31 Could feel going over the CL. CG=6.5
TST63003 / GND2	06/30 14:55	ACY	182	0	0	182	31	170/10	28.1	129726	80 knot S-Turns. [illegible] 13/31 [illegible] Definitely felt it go over the CL on the 2nd turn (L-R) could be due to [illegible] [illegible]
TST63004 / GND2	06/30 14:58	ACY	152	0	0	152	13	200/11	27.7	129326	80 knot S-Turns. CG=6.5. [illegible]
TST63005 / GND2	06/30	ACY	91	0	0	91	-	-	-	-	Stationary

Data Test Name (.DAT file) /Directory DEC315	Date (1992) & Time	Test Site	Total Test Time (Sec)	T/O Time in Air (Sec)	Land Time in Air (Sec)	Time on Gnd (Sec)	RW	Wind Dir & Speed	Fuel per 1000 lbs.	A/C Gross Wgt	Test Description And Comments
TST63006/GND2	06/30 15:09	ACY	91		0	40	31	200/15	26.5	128126	Cross winds T/O.
TST63007 / GND2	06/30 15:14	ACY	91	0		84	13	200/15	25.8	127426	Cross winds landing. Coastdown. CG=6.5
TST63008 / GND2	06/30 15:23	ACY	152	0	0	152	31	180/10	24.8	126426	80 knot S-Turns. Start on right of 31. CG=6.5
TST63009 / GND2	06/30 15:29	ACY	91		0	31	13	180/10	23.9	125526	Cross winds T/O. Turn & straight into roll.
TST63010 / GND2	06/30 15:35	ACY	91	0		82	13	180/10	23.2	124826	Cross winds landing. Coastdown. CG=6.5
TST63011 / GND2	06/30 15:43	ACY	182	0	0	182	31	180/10	22.7	124326	80 knot S-Turns. Glitch in DAT file. Start R of 31. CG=6.5
TST63012 / GND2	06/30 15:46	ACY	91		0	21	13	180/14	21.9	123526	Cross winds T/O. CG=6.5
TST63013/GND2	06/30 15:52	ACY	91	0		73	13/31	180/10	21.2	122826	Cross winds landing Coastdown. CG=6.5
TST7101 / GND2	07/01 09:58	ACY	170	0	0	170	31	280/10	29.5	131126	80 knot S-Turns. left of 31. Seemed to straighten out over CL
TST7102 / GND2	07/01 10:02	ACY	170	0	0	170	13	290/8	29.2	130826	80 knot S-Turns. start left of 13
TST7103 / GND2	07/01 10:04	ACY	170	0	0	170	31	270/10	28.7	130326	60 knot S-Turns. start left of 31
TST7104 / GND2	07/01 10:19	ACY	170	0	0	170	13	260/8	27.9	128526	60 knot S-Turns. start left of 13
TST7105 / GND2	07/01 10:24	ACY	170	0	0	170	31	270/8	27.6	[illegible]	60 knot S-Turns. start right of 31
TST7106 / GND2	07/01 10:29	ACY	170	0	0	170	13	[illegible]	[illegible]	[illegible]	60 knot S-Turns. start [illegible] of 13. [illegible]
TST7107 / GND2	07/01 10:34	ACY	170	0	0	170	31	[illegible]	26.6	[illegible]	60 knot S-Turns. [illegible] on [illegible] but [illegible] on. start right of 31
TST7108 / GND2	07/01 11:14	ACY	170	0	0	170	13	240/8	24.3	125926	60 knot S-Turns. start right on 13. Full turn at end of [illegible] to look at tiller use.
TST7109 / GND2	07/01 11:17	ACY	170	0	0	170	31	270/9	23.8	125426	60 knot S-Turns. start left on 31

Data Test Name (.DAT File) /Directory DEC115	Date (1992) & Time	Test Site	Total Test Time (Sec)	T/O Time [illegible]	Land Time [illegible]	Time on Gnd (Sec)	RW	Wind [illegible] Speed	[illegible]	[illegible]	[illegible]
TST7110 / GND2	07/01 11:35	ACY	170	0	0	170	13	300/10	23.0	124626	60 knot S-Turns. start left on 13
TST7111 / GND2	07/01 11:39	ACY	170	0	0	170	31	300/10	22.5	124126	40 knot S-Turns. start left on 31
TST7112 / GND2	07/01 11:44	ACY	170	0	0	170	13	270/10	22.1	123726	40 knot S-Turns. start left on 13
TST7113 / GND2	07/01 11:53	ACY	170	0	0	170	31	270/10	21.6	123226	40 knot S-Turns. start right on 31
TST7114 / GND2	07/01 11:57	ACY	170	0	0	170	13	270/10	21.5	123126	40 knot S-Turns. start right on 13
TST7115 / GND2	07/01 12:04	ACY	170	0	0	170	ramp	270/10	21.2	122826	power back 30 secs. power forward 30 secs. hold for 30 seconds
TST7116 / GND2	07/01 12:06	ACY	170	0	0	170	ramp	270/10	20.9	122526	Minimum radius turn clockwise (slow)
TST7117 / GND2	07/01 12:09	ACY	170	0	0	170	ramp	270/10	20.6	122226	Minimum radius turn counter clockwise (slow)
TEST4/JUNE2T24	06/01 15:10	ACY	123		0	38	31	360/8	24.7	126326	Normal T/O
TEST5/JUNE2T24	06/01 15:20	ACY	123	0		114	31	350/8	22.7	124326	Landing to coastdown. 1520 start braking. 1521 stop & start taxi to ramp. 1527 at ramp.
TEST600/JUNE2T24	06/02 07:04	ACY	92		0	51	31	calm	29.9	131526	T/O - seemed rough on runway. OAT=54°/54°
TEST601/JUNE2T24	06/02 07:11	ACY	92	0		81	31	calm	28.4	130026	Definite bump in 1st part edge of RW still slightly damp from early rain. Main part of RW dry. Sunny, clouds dispersing. Turn at end of RW. Probably not complete data.
TEST700/JUNE2T24	06/02 07:14	ACY	92		0	32	13	calm	28.4	130026	T/O.
TEST8/JUNE2T24	06/02 07:20	ACY	92	0		83	31	calm	26.6	128226	Land, coastdown, turn end of RW Hanger to [illegible] OAT=[illegible]/54°
TEST9/JUNE2T24	06/02 07:24	ACY	74		0	26	13	calm	26.6	128226	T/O. OAT=56.9°
TEST10/JUNE2T24	06/02 07:29	ACY	74	0		66	31	calm	25.5	127126	Land-coastdown, off RW for commuters. OAT=57°

Data Test Name (.DAT File) /Directory [illegible]	Date (1992) & Time	Test Site	Total Test Time (Sec)	T/O Time [illegible]	Land Time [illegible]	Time on Gnd (sec)	RW	Wind Direc Speed	Fuel [illegible] 1000 lbs	A/C Gross Wgt	Remarks [illegible]
TEST11/JUNE2T24	06/02 07:34	ACY	74		0	46	13	calm	25.2	127126	T/O
TEST12/JUNE2T24	06/02 07:40	ACY	74	0		65	31	calm	23.3	124926	Land-coastdown. Last of 15° flap landings. Returned to ramp to let Joe off. OAT=58.3°
TEST13/JUNE2T24	06/02 07:52	ACY	74		0	42	13	320/4	22.6	124226	T/O. Felt smooth on liftoff. Hanger to left. OAT=58°/54°
TEST14/JUNE2T24	06/02 08:00	ACY	74	0		68	31	350/5	21.5	123126	Land-coastdown. 1st of 30° flap landings. Rough landing.
TEST15/JUNE2T24	06/02 08:05	ACY	74		0	46	13	330/5	21.3	122926	Hesitation on brake release. Engines down then up. OAT=59°/54°
TEST16/JUNE2T24	06/02 08:12	ACY	74	0		65	31	350/5	19.6	121226	Land & coastdown. Hanger on left.
TEST17/JUNE2T24	06/02 08:14	ACY	74		0	17	13	350/5	19.6	121226	T/O. Data switch turned on late in cockpit. OAT=59°
TEST18/JUNE2T24	06/02 08:20	ACY	74	0		61	31	020/5	18.1	119726	Land-coastdown. Seemed to be 'clattering' thru floor then normal during coastdown. Seemed bad when nose whl touched down.
TEST19/JUNE2T24	06/02 08:26	ACY	74		0	24	13	010/5	17.8	119426	T/O. OAT=61°
TEST20/JUNE2T24	06/02 08:32	ACY	74	0		59	31	020/4	16.6	118226	Land-coastdown. Hard bounce on nosewheel. Firm stop. OAT=61°
TEST22/JUNE2T24	06/02 08:53	ACY	74		0	27	13	020/4	15.1	116726	T/O. Cooling the brakes. OAT=61°.
TEST23/JUNE2T24	06/02 09:04	ACY	74	0		68	31	340/5	13.0	114626	Land-Coastdown. Last one. OAT=62°.
TEST24/JUNE2T24	06/02 09:15	ACY	60	0	0	60	31	020/4	15.1	116726	Panic stop transferred from video to this disk file. Replaces TEST21.DAT. Returned to ramp to refuel.
TEST30/JUNE2R	06/02 11:18	ACY	184	0	0	184	**	340/5	30.4	132026	Taxi on PCC. Run with 30 blocks. Test [illegible] at 20 blocks. [illegible]/54°, 130°. ** [illegible] dry concrete LT/PCC
TEST31/JUNE2R	06/02 11:23	ACY	153	0	0	153	13	310/5	29.9	131526	Taxi on Asphalt, set for 35 blocks. 310°
TEST32/JUNE2R	06/02 11:48	ACY	153	0	0	153	ramp LT	090/5	28.5	130126	Min Rad, Wet (flooded by fire truck. L Turn. OAT=69°.

Data Test Name (.DAT File) /Directory [illegible]	Date (1992) & Time	Test Site	Total Test Time (Sec)	[illegible]	Ramp Time [illegible]	Time [illegible]	RW	Wind Dir & Speed	Fuel [illegible]	A/C Gross Wt	[illegible]
TEST33/JUNE2R	06/02 11:51	ACY	92	0	0	92	ramp LT	090/5	27.8	129426	Min Rad, Wet, L Turn, with quick release.
TEST34/JUNE2R	06/02 11:55	ACY	92	0	0	92	ramp RT	090/5	27.6	129226	Min Rad, Wet , R Turn, with quick release.
TEST35/JUNE2R	06/02 12:10	ACY	184	0	0	184	31	calm	26.9	128526	Free release followed by 40 knot S-turns. More data on tape. Jess- very minimal rudder input needed.
TEST36/JUNE2R	06/02 12:20	ACY	246	0	0	246	13	170/8	26.2	127826	Free release followed by 40kt S-Turn. Jess made 'shallower' turns than on the previous run. Last run left rubber on the RW.
TEST37/JUNE2R	06/02 12:26	ACY	246	0	0	246	31	calm	25.8	127426	Free release, 40kt S-Turn, plug pulled in middle of run.
TEST38/JUNE2R	06/02 12:32	ACY	246	0	0	246	13	130/5	25.2	126826	Free release, 60kt S-Turn, reverse thrust last turn, 10 blocks at end. OAT=66.3°.
TEST39/JUNE2R	06/02 12:37	ACY	215	0	0	215	31	180/7	25.0	126626	Free release, 60kt S-turn.
TEST40/JUNE2R	06/02 12:42	ACY	215	0	0	215	13	180/7	24.6	126226	Free release, 60kt S-turn.
TEST41/JUNE2R	06/02 12:50	ACY	153	0	0	153	31	150/5	23.1	124726	Free release, 80kt S-Turn. OAT=66°. Seems more steering rattle than at lower speeds.
TEST42/JUNE2R	06/02 13:03	ACY	184	0	0	184	13	-	22.2	123826	Free release, R turn, 80kt S-turn.
TEST43/JUNE2R	06/02 13:13	ACY	166	0	0	166	31	160/4	21.2	122826	Free release, L turn, 80kt S-turn. OAT=65°.
TEST44/JUNE2R	06/02 13:21	ACY	153	0	0	153	13	170/6	20.7	122326	40kt S-turn, Tiller. OAT=65°.
TEST46/JUNE2R	06/02 13:45	ACY	182	0	0	182	31	170/5	19.7	121326	20kt S-turn. Tiller. #3 shut down.
TEST47/JUNE2R	06/02 13:54	ACY	304	0	0	304	13	190/5	19.4	121026	20kt S-turn, #3 shut down. Tiller
TEST48/JUNE2R	06/02 14:03	ACY	304	0	0	304	31	200/[illegible]	19.0	120[illegible]26	20kt S-turn, #3 shut down, [illegible] [illegible]
TEST49/JUNE2R	06/02 ??	ACY	91	0	0	91	ramp	180/3	18.7	120326	OAT=66°/56°. Min Rad 360°.

Data Test Name (.DAT file) /Directory DEC313	Date (1992) & Time	Test Site	Total Test Time (sec)	T/O Time in Air (sec)	Land Time in Air (sec)	Time on Gnd (sec)	RW	Wind Dir & Speed	Fuel per 1000 lbs.	A/C Gross Wgt	Test Description and Comments
TEST50/JUNE2R	06/02 14:20	ACY	91	0	0	91	ramp	180/3	18.6	120226	Min Rad 360°
TEST51/JUNE2R	06/02 14:23	ACY	91	0	0	91	ramp	180/3	18.4	120026	Min Rad 360°
TEST60 / JUNE3	06/03 21:10	ACY	61	0	0	61	ramp	-	30.8	132426	Power back ZFW 101,700
TEST61 / JUNE3	06/03 21:16	ACY	73		0	43	31	220/7	28.8	130426	T/O
TEST62 / JUNE3	06/02 21:27	ACY	73	0		63	13	220/7	27.6	129226	Landing, step 1 on lights. OAT=63°
TEST63 / JUNE3	06/03 21:30	ACY	73	0	0	73	31	220/7	27.6	129226	T/O, not all on disk
TEST64 / JUNE3	06/03 21:41	ACY	73	0		62	13	calm	25.1	126726	Landing, step 2 edge 11
TEST65 / JUNE3	06/03 21:49	ACY	73		0	42	31	calm	24.5	126126	T/O. Change pilots. OAT=63°
TEST66 / JUNE3	06/03 21:59	ACY	73	0		51	13	170/5	23.2	124826	Landing, step 3. Edge 5, CL ARP 4
TEST67 / JUNE3	06/03 22:01	ACY	73		0	32	31	170/5	22.1	123726	T/O
TEST68 / JUNE3	06/03 22:12	ACY	73	0		70	13	210/4	-	122826	Landing, step 5
TEST69 / JUNE3	06/03 22:14	ACY	73		0	43	13	220/5	20.3	121926	T/O step 5
TEST70 / JUNE3	06/03 22:26	ACY	73	0		45	31	180/5	17.6	119226	Landing step 5. Heavy loading - hard braking
TST92202 / 09-22	09/22	ACY	142	0	0	142				-	
TST92203 / 09-22	09/22	ACY	227		0	45				-	
TST92204 / 09-22	09/22	ACY	227	0	0	227				-	
TST92205 / 09-22	09/22	ACY	199	0	0	199				-	
TST92206 / 09-22	09/22	ACY	142	0	0	142				-	
TST92207 / 09-22	09/22	ACY	142	0	0	142				-	

Data Test Name (.DAY file) /Directory DEC(1)	Date (1992) & Time	Test Site	Total Test Time (Sec)	T/O Time (in Sec)	Decel Time (in Sec)	Time on Gnd (Sec)	RW	Wind Dir & Speed	Fuel per 1000 lbs	A/C Gross Wgt	[illegible] Remarks
TST92208 / 09-22	09/22	ACY	142	0	0	142				-	
TST92209 / 09-22	09/22	ACY	142	0	0	142				-	
TST92210 / 09-22	09/22	ACY	114	0	0	114				-	
TST92211 / 09-22	09/22	ACY	114	0	0	114				-	
1105_01 / 1105&6	11/05 06:40	JFK	170	0	0	170	13L	340/5	35.6	134200	Zero Fuel Wgt 98600 Trim 6.5. Alt 29.78
1105_02 / 1105&6	11/05 07:17	JFK	57	0	0	57	31R	340/5	32.2	130800	Trim 6.5.
1105_03 / 1105&6	11/05 08:16	JFK	85	0	0	85	31R	010/14	27.6	126200	Trim 6.5. Alt 29.83.
1105_04 / 1105&6	11/05 08:42	JFK	57	0	0	57	31R	010/14	24.0	122600	Trim 6.5. Not idle at start. One appl of sand
1105_05 / 1105&6	11/05 09:08	JFK	57	0	0	57	31R	360/10	19.9	118500	Trim 6.5. * Two appl of sand.
1106_01 / 1105&6	11/06 06:13	JFK	57	0	0	57	31R	330/17	37.9	136500	Trim 6.5. Alt 29.87. A/C slightly R of CL.
1106_02 / 1105&6	11/06 ??:??	JFK	255	0	0	255	31R*	-	33.5	132100	No effect. Trim 6.5. * Octagon TypeII S-Turns
1106_03 / 1105&6	11/06 08:10	JFK	57	0	0	57	31R*	320/8	32.5	131100	Trim 6.5. * UCAR 5.1 Slippery
1106_04 / 1105&6	11/06 08:42	JFK	57	0	0	57	31R*	300/6	28.4	127000	Trim 6.5. Better. UCAR 5.1 1 sand
1106_05 / 1105&6	11/06 09:07	JFK	57	0	0	57	31R*	300/6	25.5	124100	Same. Trim 6.5. Alt 29.97. UCAR 5.1 2 sand
TST70701/TYPEII	07/07 14:22	JFK	152	0	0	152	13L	200/5	38.1	137950	High speed/braking. Regular pavement
TST70702/TYPEII	07/07 14:40	JFK	91	0	0	91	13L	200/7	36.8	138000	High speed braking. Wet by truck.
TST70703/TYPEII	07/07 15:02	JFK	91	0	0	91	13L	190/6	35.5	134[illegible]	High speed braking. Wet by truck.
TST70704/TYPEII	07/07 15:29	JFK	60	0	0	60	13L	200/7	32.8	132000	High speed braking. Lost left gear [illegible] POT. Wet by truck.

Data Test Name (.DAT file) /Directory [illegible]	Date (1992) & Time	Test Site	Total Test Time (sec)	T/O Time in Air (Sec)	Land Time in Air (Sec)	Time on Gnd (sec)	RW	Wind Dir & Speed	Fuel [illegible]	A/C Gross Weight	Test Description [illegible]
TST70705/TYPEII	07/07 15:57	JFK	60	0	0	60	13L	200/6	30.0	129225	High speed braking. RM IB Tire blow out.
TST70801/TYPEII	07/08 14:18	JFK	60	0	0	60	13L	calm	26.7	125900	High speed braking. 1st app Deicing fluid. Alt=30.09. Out speed 89k.
TST70802/TYPEII	07/08 15:04	JFK	60	0	0	60	13L	260/4	24.5	123700	High speed braking. 3rd app Deicing fluid. Alt=30.08 Out speed 105k.
TST70803/TYPEII	07/08 16:11	JFK	60	0	0	60	13L	calm	21.4	120600	High speed braking. Applied UCAR. Deicing fluid. Hit data twice. Out speed 105k.
TST70804/TYPEII	07/08 17:27	JFK	60	0	0	60	13L	calm	37.2	136400	High speed braking.1st app Deicing fluid. Took on fuel before test. Out speed 94k. Alt=30.10
TST70805/TYPEII	07/08 17:51	JFK	60	0	0	60	13L	060/3	34.1	133300	High speed braking.2nd app. Deicing fluid. Out speed 92k.
TST70806/TYPEII	07/08 18:21	JFK	60	0	0	60	13L	060/3	30.2	129400	High speed braking.3rd app Deicing fluid. No video. Zvanya data
TST71001/TYPEII	07/10 14:24	LGA	73	0	0	73	22	300/7	39.4	138600	L POT bad. Wet by truck. Alt=29.86
TST71002/TYPEII	07/10 14:55	LGA	60	0	0	60	22	290/7	35.8	135000	1 level deicing fluid. Broom 1st application type II. Alt=29.85
TST71003/TYPEII	07/10 15:17	LGA	60	0	0	60	22	290/5	33.3	132500	3 level deicing fluid. 3rd application Type II.
TST71004/TYPEII	07/10 15:35	LGA	60	0	0	60	22	290/5	30.2	129400	6 level deicing fluid. 4th, 5th & 6th applications type II.
TST71005/TYPEII	07/10 15:56	LGA	60	0	0	60	22	290/5	27.7	126900	9 level deicing fluid. 7th, 8th & 9th applications type II.
TST71006/TYPEII	07/10 16:13	LGA	60	0	0	60	22	280/6	24.8	124000	12 level deicing fluid 10th, 11th & 12th applications type II.
TST71007/TYPEII	07/10 16:48	LGA	60	0	0	60	22	290/5	22.7	121900	12 level deicing fluid and applied sand.
TST71008/TYPEII	07/10 17:00	LGA	60	0	0	60	22	280/6	20.0	119200	washed & broomed (some sand contamination) applied UCAR.
TST71009/TYPEII	07/10 17:18	LGA	60	0	0	60	22	-	16.7	115900	UCAR, 6 levels deicing fluid. 1st-6th applications type II.

Data Test Name (.DAT file) /Directory DEC315	Date (1992) & Time	Test Site	Total Test Time (Sec)	T/O Time in Air (Sec)	Land Time in Air (Sec)	Time on Gnd (Sec)	RW	Wind Dir & Speed	Fuel per 1000 lbs	A/C Gross Wgt	Test Description and Comments
TST82701/08-27	08/27 00:08	JFK	57	0	0	57	13L	-	41.0	140223	dry mode. tare run. **ALL 08-27 TESTS PLOTS ARE FLATLINED. DATA POINTS DO NOT MOVE. POOR DATA.**
TST82702/08-27	08/27 00:17	JFK	57	0	0	57	13L	-	39.6	138823	1st app type II. Poor data
TST82703/08-27	08/27 00:31	JFK	57	0	0	57	13L	-	38.8	138023	2nd & 3rd app type II. Poor data
TST82704/08-27	08/27 00:56	JFK	57	0	0	57	13L	-	35.6	134823	4th-6th app type II. Poor data
TST82705/08-27	08/27 1:08	JFK	57	0	0	57	13L	-	34.0	133223	7th-9th app type II. Poor data
TST82706/08-27	08/27 1:32	JFK	57	0	0	57	13L	-	31.0	130223	10th-12th app type II. Poor data. Viscosity sample/ type II.
TST82707/08-27	08/27 1:45	JFK	57	0	0	57	13L	-	30.0	129223	1 app potassium acetate. Poor data
TST82708/08-27	08/27 2:36	JFK	57	0	0	57	13L	-	26.5	125723	Surface flushed, wet by truck, light sweeper several passes. 1 app potassium acetate. Poor Data
TST51901/05-19 $	5/19/93 21:40	DFW	113	0	[redacted]	103	31L	-	-	-	Arrival landing, No recording.
TST51902/05-19	5/19/93 22:12	DFW	113	0	0	113	13R	-	-	-	Landing config,CL event at very end of recording. 25 blocks.
TST51903/05-19	5/19/93 22:17	DFW	113	0	0	113	31L	-	-	-	T/O config, CL, 10 blocks. Felt the bump.
TST51904/05-19	5/19/93 22:22	DFW	142	0	0	142	13R	-	-	-	Landing config, CL. Tire checked because of smell. Also hot. Will T/O after next test.
TST51905/05-19	5/19/93 22:33	DFW	85	0	0	85	31L	-	-	-	T/O config.
TST51906/05-19	5/19/93 22:37	DFW	85	[redacted]	0	27	13R	-	-	-	T/O to cool tires. [illegible] because of noise [illegible] Felt rough towards the end [illegible]
TST51907/05-19	5/19/93 23:09	DFW	85	0	0	85	31L	-	-	-	T/O config CL. Seemed [illegible] in center.
TST51908/05-19	5/19/93 23:13	DFW	142	0	0	142	13R	-	-	-	Landing config. Railing close to bump.

Data Test Name (.DAT file) /Directory [illegible]	Date (1992) & Time	Test Site	Total Test Time (s)	[illegible]	[illegible]	[illegible]	RW	Wind Dir & Speed	[illegible]	[illegible]	[illegible]
TST51909/05-19	5/19/93 23:18	DFW	85	0	0	85	31L	-	-	-	T/O config. Seemed that 70 knots was more achievable speed over the bump.
TST51910/05-19	5/19/93 23:26	DFW	142	0	0	142	13R	-	-	-	T/O config. Railing again.
TST51911/05-19	5/19/93 23:37	DFW	85		0	41	31L	-	-	-	T/O full acceleration. Leave. Special approval for noise restriction.
TST11401/01-14	1/14/93 6:40	JFK	57		0	36	-	-	-	-	
TST11402/01-14	1/14/93 7:07	JFK	113	0		91	-	-	-	-	
TST11403/01-14	1/14/93 8:07	JFK	57	0	0	57	-	-	-	-	
TST11404/01-14	1/14/93 8:13	JFK	57	0	0	57	-	-	-	-	
TST11405/01-14	1/14/93 8:28	JFK	57	0	0	57	-	-	-	-	
TST11406/01-14	1/14/93 8:37	JFK	57	0	0	57	-	-	-	-	
TST11407/01-14	1/14/93 8:44	JFK	57	0	0	57	-	-	-	-	
TST11408/01-14	1/14/93 9:56	JFK	57		0	35	-	-	-	-	
825TST01/B-727	8/25/93 20:58	PHX	142	0	0	142	8L	-	-	-	
825TST02/B-727	8/25/93 21:01	PHX	142	0	0	142	26R	-	-	-	
825TST03/B-727	8/25/93 21:10	PHX	284	0	0	284	-	-	-	-	
825TST04/B-727	8/25/93 21:20	PHX	313	0	0	313	-	-	-	-	
825TST05/B-727	8/25/93 21:31	PHX	142	0	0	142	8L	-	-	-	
825TST06/B-727	8/25/93 21:34	PHX	142	0	0	142	26R	-	-	-	

Data Test Name (.DAT file) /Directory DEC315	Date (1993) & Time	Test Site	Total Test Time (Sec)	T/O Time in Air (Sec)	Land Time in Air (Sec)	Time on Gnd (Sec)	RW	Wind Dir & Speed	Fuel Per 1000 lbs	A/C Gross Wt	Test Description and Comments
825TST07/B-727	8/25/93 21:39	PHX	313	0	0	313	-	-	-	-	
825TST08/B-727	8/25/93 21:45	PHX	313	0	0	313	-	-	-	-	
825TST09/B-727	8/25/93 21:53	PHX	313	0	0	313	-	-	-	-	
825TST10/B-727	8/25/93 22:10	PHX	142	0	0	142	26L	-	-	-	
825TST11/B-727	8/25/93 22:14	PHX	142	0	0	142	8R	-	-	-	
825TST12/B-727	8/25/93 22:17	PHX	142	0	0	142	26L	-	-	-	
825TST13/B-727	8/25/93 22:20	PHX	142	0	0	142	8R	-	-	-	
825TST14/B-727	8/25/93 22:30	PHX	284	0	0	284	-	-	-	-	
825TST15/B-727	8/25/93 ?	PHX	313	0	0	313	-	-	-	-	
825TST16/B-727	8/25/93 ?	PHX	398	0	0	398	-	-	-	-	

APPENDIX B
Force Calibration Procedure

The aircraft was placed on screw jack stands, supported at standard jack points, and a zero force output was recorded for the three standard directions; vertical shear, drag shear, and side shear for each landing gear.

To Calibrate Vertical Shear:
Individually, the nose gear, left main gear, and right main gear of the aircraft were lowered incrementally onto a load cell platform. Load cell output and strain gage output were recorded for several different loadings, up to full aircraft weight.

To Calibrate Drag Shear:
Individually, the nose gear, left main gear, and right main gear of the aircraft were lowered onto a load cell platform to approximate normal vertical load. The load cell platform was loaded longitudinally at several different weights up to 5000 lbs. Load cell output and strain gage output were recorded for the different loadings.

To Calibrate Side Shear:
Individually, the nose gear, left main gear, and right main gear of the aircraft were lowered onto a load cell platform to approximate normal vertical load. The load cell platform was loaded laterally at several different weights up to 5000 lbs. Load cell output and strain gage output were recorded for the different loadings.

APPENDIX C
Listing of Data Channels

Channel	Units	Range
CG Acceleration - Lateral	G's	-.5 to .5
CG Acceleration - Longitudinal	G's	-1 to 1
CG Acceleration - Normal	G's	-1 to 1
Throttle Position - #3 Engine	% travel	0 to 100
Flap Position	Degrees	0 to 40
Elevator Position	Degrees	-10 to 20
Rudder Position	Degrees	-25 to 25
Aileron Position	Degrees	-20 to 20
Brake Pressure - LMG; Left Axle	psi	0 to 3000
Brake Pressure - LMG; Right Axle	psi	0 to 3000
Brake Pressure - RMG; Right Axle	psi	0 to 3000
Brake Pressure - RMG; Left Axle	psi	0 to 3000
Ground Distance	feet	121.92 pulses/ft
Ground Speed; from Optical Sensor	mph	0.2 to 250
Strain Gages		
Vertical Shear - RMG; Right Axle	pounds	
Vertical Shear - RMG; Left Axle	pounds	0 to 200000 (sum)
Vertical Shear - LMG; Right Axle	pounds	
Vertical Shear - LMG; Left Axle	pounds	0 to 200000 (sum)
Vertical Shear - NG; Right Axle	pounds	
Vertical Shear - NG; Left Axle	pounds	0 to 20000 (sum)
Drag Shear - RMG; Right Axle	pounds	
Drag Shear - RMG; Left Axle	pounds	0 to 50000 (sum)
Drag Shear - LMG; Right Axle	pounds	
Drag Shear - LMG; Left Axle	pounds	0 to 50000 (sum)
Drag Shear - NG; Right Axle	pounds	
Drag Shear - NG; Left Axle	pounds	0 to 10000 (sum)
Side Shear - RMG	pounds	0 to 50000
Side Shear - LMG	pounds	0 to 50000
Side Shear - NG	pounds	0 to 10000
*Pitch Angle	degrees	-90 to 90
*Roll Angle	degrees	-180 to 180
*True Heading	degrees	-180 to 180

* Only Utilized for Takeoffs and Landings

** Aircraft instrumentation uses standard sign convention; right handed coordinates with forward being positive x. Positive accelerations give negative forces.

APPENDIX D

Data Reduction Software
Program Listing

```
' * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
' *                                                                      *
' *     PROGRAM TO:                                                      *
' *         Read signals from a Eidel binary file system                 *
' *                  and write to ASCII file.                            *
' *                                                                      *
' *                      Bill Cavage                                     *
' *              Based on a program by Gordon Hayhoe                     *
' * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

'
'  declare subs and functions
'
DECLARE SUB LPTB (MM%, T!, B!, A1!(), A2!(), BZERO!)
DECLARE SUB TTRAN (A1!(), A2!(), B0!(), B1!(), B2!(), M%, T!, FREQ!, ABZ!,
PHS!)
DECLARE SUB SETTANFILT ()
DECLARE SUB TAN2FILT (W!, J&)
DECLARE SUB SETFILTERS ()
DECLARE FUNCTION RI0! (X!)
DECLARE FUNCTION GETDOUBLEHEX! (ISIG&, I&)
DECLARE FUNCTION GETMSDLSD! (J&, ISIG&, IREC&, SCRATE$, PCHRAT!, ROLRAT!,
YAWRAT!)
DECLARE FUNCTION GETDEC! (ISIG&, IREC&)
DECLARE FUNCTION GETREAL! (ISIG&, IREC&)
DECLARE FUNCTION GETHEX (ISIG&, IREC&)

'
'  define variables, dimension arrays, and set initial values
'
DEFLNG I-N
DEFSTR S
DIM NADDC(100), NADDT(100), NELMC(100)
DIM CPHDG(100), RATE(200), FORCECAL(20), ISIGLINE(200), IWORD(200),
SUNIT$(200)
DIM SWNAME$(200), WNUM(200), WTYP(200), WFNUM(200), EIDELSIG(200), NTAG(200)
DIM SKIP$(200), GAIN(200), OSET(200), CADD(200), VALUE(200), STAT$(200)
DIM RMAXVAL(200), RMINVAL(200), RMAXTIM(200), RMINTIM(200), TOTVAL(200)
COMMON SHARED TRUE, FALSE
COMMON SHARED TSP, ISIGLINE(), TSIGNAME$(), IWORD(), LAST$(), INDX()
TRUE = -1: FALSE = 0
NCNT = 0: NCORR = 1: SWCH$ = "OFF"
CLS : PRINT : PRINT

'
'  set variable inputs
'
SPATH$ = "C:\DEC315\JUNE2\"
STESTSIG$ = "B-727"
STESTNAM$ = "TEST34"
SFILNAM$ = "C:\QB\GLDATA\T34"
'SFILNAM$ = "CONS:"
SDATNAM$ = "GLDATMAN"
SCALNAM$ = "GLCALDAT"
TANFILTFREQ = 5!
TSTART = 0: TEND = 90
SCOND$ = "Minimum Radius Turn"
STITLE1$ = "B-727 GROUND/FLIGHT TEST DATA FILE"
```

```
STITLE2$ = SCOND$ + " Data from Manning Data Set; "
NPRNT = 2
STATOP$ = "NO"
SCRATE$ = "NO"
SCOLUM$ = "NORMAL"
SCOLTIT$ = ""

'
'  set file names
'
SIGFILE$ = SPATH$ + STESTSIG$ + ".SIG"
SFORFIL$ = SPATH$ + STESTSIG$ + ".FOR"
SDATFIL$ = SPATH$ + STESTNAM$ + ".DAT"
SPLBFIL$ = SPATH$ + STESTNAM$ + ".PLB"
SCALDAT$ = SCALNAM$ + ".DAT"
SDATMAN$ = SDATNAM$ + ".DAT"
SOPFIL$ = SFILNAM$ + ".DAT"
STATFIL$ = SFILNAM$ + ".STA"
STITLE2$ = STITLE2$ + SDATFIL$
PRINT "               CONVERTING "; SDATFIL$
PRINT : PRINT

'
'  data manipulation input file
'
OPEN SDATMAN$ FOR INPUT AS #5
INPUT #5, NCOLELM
FOR I = 1 TO NCOLELM
   INPUT #5, NELMC(I)
NEXT I
INPUT #5, SFCHK$
IF SFCHK$ <> "#" THEN
   PRINT "               ERROR:  BAD DATA FILE SETUP; CAN NOT INTERPRET "
   PRINT "                       "; SDATMAN$; " FOR MAIN MODULE"
   PRINT : PRINT
   STATOP$ = "NO"
   GOTO 500
END IF
INPUT #5, NCOLADD
FOR I = 1 TO NCOLADD
   INPUT #5, NADDC(I), NADDT(I)
NEXT I
CLOSE #5

'
'  check if input file is valid
'
OPEN SDATFIL$ FOR BINARY AS #1
GET #1, , ID                                  ' signed 16 bit integer.
IF EOF(1) = -1 THEN
  PRINT "              ERROR:  FILE DOES NOT EXIST."
  PRINT : PRINT
  CLOSE #1
  KILL DATFILE$
  STATOP$ = "NO"
  GOTO 500
END IF
CLOSE #1

'
'  obtain information from format file
'
```

```
OPEN SFORFIL$ FOR INPUT AS #2
FOR I = 1 TO 9
   INPUT #2, TEMP
NEXT I
INPUT #2, NWORDS
INPUT #2, TEMP
INPUT #2, TEMP
INPUT #2, SYNCVAL$
CLOSE #2

'
'  convert binary sync value to decimal
'
AMOUNT = 0: VALUE = 0: DIGIT = 0
FOR I = 1 TO 12
   SDIG$ = MID$(SYNCVAL$, 13 - I, 1)
   DIGIT = VAL(SDIG$)
   IF DIGIT = 1 THEN
      AMOUNT = AMOUNT + 2 ^ (I - 1)
   END IF
NEXT I
FSYNCVAL = AMOUNT

'
'  obtain time information from .plb file
'
OPEN SPLBFIL$ FOR INPUT AS #2
LINE INPUT #2, STEMP$: LINE INPUT #2, STEMP$
INPUT #2, DAYOFMONTH$
INPUT #2, TIMEOFDAY$
FOR I = 1 TO 8
  INPUT #2, WORDLEN
NEXT I
LINE INPUT #2, STEMP$: LINE INPUT #2, TEMP$
INPUT #2, STEMP$
LINE INPUT #2, STEMP$
INPUT #2, BITFREQ
FFREQ = 1000! * BITFREQ / (WORDLEN * NWORDS)
CLOSE #2
TINTERVAL = 1! / FFREQ
TSP = TINTERVAL
FFNYQUIST = 1! / (TSP * 2!)
IF TANFILTFREQ > FFNYQUIST THEN TANFILTFREQ = FFNYQUIST
TVALID = TSTART + (10 * TINTERVAL)

'
'  calculate filter weights, set filters
'
CALL SETFILTERS
CALL SETTANFILT

'
'  determine word name, word number, frame number, and word type
'
NWORDS = 0
GNUM = 0
OPEN SIGFILE$ FOR INPUT AS #1
OPEN SCALDAT$ FOR INPUT AS #4
LINE INPUT #4, STEMP$
IF STEMP$ <> "$" THEN
    PRINT "          ERROR:  BAD CALIBRATION FILE"
    PRINT : PRINT
```

```
        STATOP$ = "NO"
        GOTO 500
    END IF
    LINE INPUT #1, STEMP$                         ' clear first line of .SIG file.
    DO                                            ' loop until no more word entries
        LINE INPUT #1, ST$                        ' one complete line from .SIG file.
        IF ST$ = "#" THEN EXIT DO
        IST1 = INSTR(ST$, "*") + 1                ' number of characters to "*"
        IST2 = INSTR(ST$, ";")                    ' number of characters to first ;
        IST3 = IST2 - IST1                        ' length of channel name
        SNFIND$ = MID$(ST$, ISTCNT + 1, 1)
        IF SNFIND$ = ";" THEN
            SFNUM$ = "0"
        ELSE
            IST4 = INSTR(ISTCNT + 1, ST$, ";")
            SFNUM$ = MID$(ST$, ISTCNT + 1, IST4)
        END IF
        ISTCNT = IST2
        ICNT = 1
        SWCH$ = "OFF"
        DO
            ISTCNT = ISTCNT + 1
            SNFIND$ = MID$(ST$, ISTCNT, 1)
            IF SNFIND$ = ";" THEN
                ICNT = ICNT + 1
                IF ICNT = 2 THEN
                    ISTCNT = ISTCNT + 1
                    IST7 = INSTR(ISTCNT, ST$, ";")
                    IF IST7 - ISTCNT = 1 THEN
                        SWNUM$ = MID$(ST$, ISTCNT, 1)
                    ELSEIF IST7 - ISTCNT = 2 THEN
                        SWNUM$ = MID$(ST$, ISTCNT, 2)
                        ISTCNT = ISTCNT + 1
                    ELSEIF IST7 - ISTCNT = 3 THEN
                        SWNUM$ = MID$(ST$, ISTCNT, 3)
                        ISTCNT = ISTCNT + 2
                    END IF
                END IF
                IF ICNT = 6 THEN
                    ISTCNT = ISTCNT + 1
                    SWTYP$ = MID$(ST$, ISTCNT, 1)
                END IF
                IF ICNT = 7 THEN                                    ' presently not
                    ISTCNT = ISTCNT + 1                             ' using this
                                                                    ' routine
                    IST5 = INSTR(ISTCNT, ST$, ";")                  ' to get
                                                                    ' calibration
                    SGAN$ = MID$(ST$, ISTCNT, IST5 - ISTCNT)        ' data from .sig
                    ISTCNT = IST5                                   ' file; it has
                    ISTCNT = ISTCNT + 1                             ' not been correct
                    IST6 = INSTR(ISTCNT, ST$, ";")
                    SOST$ = MID$(ST$, ISTCNT, IST6 - ISTCNT)
                    ISTCNT = IST6
                    ICNT = ICNT + 1
                END IF
                IF ICNT = 11 THEN
                    ISTCNT = ISTCNT + 1
                    STAT$ = MID$(ST$, ISTCNT, 8)
                    SWCH$ = "ON"
                END IF
            END IF
        LOOP WHILE SWCH$ = "OFF"
```

```
    NUMB = VAL(SWNUM$) + 1
    IF NUMB > GNUM THEN
        GNUM = NUMB
    END IF
    SWNAME$(NUMB) = MID$(ST$, IST1, IST3)
    WNUM(NUMB) = VAL(SWNUM$)
    WTYP(NUMB) = VAL(SWTYP$)
    WFNUM(NUMB) = VAL(SFNUM$)
    SDIG4$ = MID$(STAT$, 4, 1)
    NTAG(NUMB) = VAL(SDIG4$)
    INPUT #4, GAIN(NUMB)
    INPUT #4, OSET(NUMB)
    INPUT #4, SUNIT$(NUMB)
    NWORDS = NWORDS + 1
LOOP
CLOSE #1
INPUT #4, STEMP$
IF STEMP$ <> "#" THEN
    PRINT "         ERROR:  BAD CALIBRATION FILE"
    PRINT : PRINT
    STATOP$ = "NO"
    GOTO 500
END IF
CLOSE #4

'
'  routine to eliminate blank spaces in .sig file
'
I = 1
DO
    IF SWNAME$(I) = "" THEN
        FOR J = I TO GNUM
            WNUM(J) = J - 1
            SWNAME$(J) = SWNAME$(J + 1)
            WTYP(J) = WTYP(J + 1)
            WFNUM(J) = WFNUM(J + 1)
            GAIN(J) = GAIN(J + 1)
            OSET(J) = OSET(J + 1)
            NTAG(J) = NTAG(J + 1)
            SUNIT$(J) = SUNIT$(J + 1)
        NEXT J
    END IF
    IF SWNAME$(I) <> "" THEN
        I = I + 1
    END IF
LOOP UNTIL I > NWORDS

'
'  mark unwanted columns; mark columns to be combined
'
FOR I = 1 TO NWORDS
    FOR J = 1 TO NCOLELM
        IF NELMC(J) = I THEN
            SKIP$(I) = "YES"
        END IF
    NEXT J
    FOR J = 1 TO NCOLADD
        IF NADDC(J) = I THEN
            CADD(I) = J
            CADD(NADDT(J)) = J
        END IF
    NEXT J
```

```
     FOR J = 1 TO NCOLADD
         IF NADDT(J) = I THEN
             SKIP$(I) = "YES"
         END IF
     NEXT J
NEXT I

'
'  eliminate channels not tagged
'
NCHANELM = 0
I = 1
DO
     IF NTAG(I) = 0 THEN
        NCHANELM = NCHANELM + 1
        FOR J = I TO NWORDS
            WNUM(J) = J - 1
            SWNAME$(J) = SWNAME$(J + 1)
            WTYP(J) = WTYP(J + 1)
            WFNUM(J) = WFNUM(J + 1)
            GAIN(J) = GAIN(J + 1)
            OSET(J) = OSET(J + 1)
            NTAG(J) = NTAG(J + 1)
            SKIP$(J) = SKIP$(J + 1)
            CADD(J) = CADD(J + 1)
            NTAG(J) = NTAG(J + 1)
            SUNIT$(J) = SUNIT$(J + 1)
        NEXT J
     END IF
     IF NTAG(I) <> 0 THEN
        I = I + 1
     END IF
LOOP WHILE SWNAME$(I) <> ""

'
'  routine to eliminate spaces form column names
'
    FOR I = 3 TO NWORDS - NCHANELM
       NSTRLEN = LEN(SWNAME$(I))
       FOR J = 1 TO NSTRLEN
           SLETSTR$ = MID$(SWNAME$(I), J, 1)
           IF SLETSTR$ = " " THEN
              MID$(SWNAME$(I), J, 1) = "_"
           END IF
       NEXT J
    NEXT I

'
'  open output file, label top, and print out headings
'
DELTAT = TINTERVAL * NPRNT
DFFREQ = 1 / DELTAT
OPEN SOPFIL$ FOR OUTPUT AS #3
PRINT #3, STITLE1$
PRINT #3, STITLE2$
PRINT #3, "Time Start = "; TSTART; ":   Time Finish = "; TEND
PRINT #3, "Time Between Samples ="; DELTAT; "("; DFFREQ; "Hz Data Frequency)"
PRINT #3,
PRINT #3, "TIME  ";
SWCH$ = "OFF"
IF SCOLUM$ = "SPECIFIED" THEN
    PRINT #3, SCOLTIT$
```

```
ELSE
    FOR I = 3 TO NWORDS - NCHANELM
       IF SKIP$(I) <> "YES" THEN
          PRINT #3, SWNAME$(I); "    ";
       END IF
    NEXT I
    IF SCRATE$ = "YES" THEN
       PRINT #3, "ROLRAT   PCHRAT";
    END IF
END IF
PRINT #3,
PRINT #3,

'
'  open Eidel file and find first data word
'
OPEN SDATFIL$ FOR BINARY AS #1
ISTART = 1
FOR I = ISTART TO 32000000
    W = GETDEC(1, I)
    IF W = FSYNCVAL THEN
         ISTART = I
         EXIT FOR
    END IF
NEXT I
FOR I = ISTART + 1 TO 5000
    W = GETDEC(1, I)
    IF W = FSYNCVAL THEN
         NSIGS = ((I - ISTART) \ 2)
         EXIT FOR
    END IF
NEXT I
'IF NSIGS <> NWORDS - NCHANELM THEN
'    PRINT #3, "      ALARM:  DISCREPENCY IN NUMBER OF WORDS SPECIFIED"
'    PRINT #3, "              CHECK FOR PROPER .SIG FILE"
'    NWORDS = NSIGS
'ELSE
    NWORDS = NSIGS
'END IF

'
'  find proper frame to match TSTART
'
SWCH$ = "OFF"
TIME = 0
I = ISTART
DO
    W = GETDEC(1, I)
    IF W = FSYNCVAL THEN
         TIME = TIME + TINTERVAL
    END IF
    I = I + 1
LOOP UNTIL TIME > TSTART
TIME = TIME - TINTERVAL
I = I - 1
ISIG = I

'
'  main data output do loop
'
DO
```

```
'
' check for sync word; search if necessary; be sure file has data
'
  W = GETDEC(1, I)
  IF W <> FSYNCVAL THEN
       I = I + 1
       IF EOF(1) = -1 THEN
           PRINT #3,
           PRINT #3, "      FILE OUT OF DATA"
           PRINT "              FILE OUT OF DATA"
           GOTO 500
       END IF
       PRINT #3,
       PRINT #3, "      ERROR:  LOSS OF SYNC; CAN'T FIND SYNC VALUE"
       PRINT #3, "              SEARCHING FOR SYNC VALUE"
       PRINT #3,
       DO
           W = GETDEC(1, I)
           IF W = FSYNCVAL THEN
               PRINT #3, "             FOUND SYNC WORD; RESUMING EXTRACTION"
               PRINT #3,
                ISIG = I
               NCNT = 0
                EXIT DO
           ELSE
               I = I + 1
               NCNT = NCNT + 1
           END IF
           IF NCNT > 10000 THEN
               PRINT #3, "             CAN'T FIND SYNC WORD; ENDING PROGRAM"
               STATOP$ = "NO"
               GOTO 500
           END IF
       LOOP WHILE W <> FSYNCVAL
  END IF
'
' go thru frame byte by byte getting data based on signal type
'
  FOR J = 1 TO 2
       IF WTYP(J) = 0 THEN
           W = GETDEC(J, I)
       ELSE
           PRINT #3, "             ERROR:  FIRST 2 FRAME WORDS ARE NOT SYNC"
           PRINT #3, "                     VALUES"
           STATOP$ = "NO"
           GOTO 500
       END IF
       ISIG = ISIG + 2
  NEXT J
  FOR J = 3 TO NWORDS                       ' start loop after sync words
       IF WTYP(J) = 0 THEN                  ' read and convert file data
           IF J > 2 THEN                    ' based on the signal type.
               W = GETMSDLSD(J, ISIG, I, SCRATE$, PCHRAT, ROLRAT, YAWRAT)
           ELSE
               W = GETDEC(J, I)
           END IF
       ELSEIF WTYP(J) = 2 THEN
           W = GETDEC(J, I)
       ELSEIF WTYP(J) = 8 THEN
           W = GETREAL(J, I)
           CALL TAN2FILT(W, J)
```

```
        ELSEIF WTYP(J) = 1 THEN
            W = GETHEX(J, I)
        ELSEIF WTYP(J) = 4 THEN
            W = GETREAL(J, I) * 5!
        ELSEIF WTYP(J) = 5 THEN
            W = GETREAL(J, I) * 10!
            CALL TAN2FILT(W, J)
        ELSEIF WTYP(J) = 6 THEN
            W = GETREAL(J, I) * 10! - 5!
            CALL TAN2FILT(W, J)
        ELSE
            PRINT #3, "      ERROR:  UNRECOGNIZABLE SIGNAL TYPE"
            STATOP$ = "NO"
            GOTO 500
        END IF
        EIDELSIG(J) = W
        VALUE(J) = (EIDELSIG(J) * GAIN(J)) + OSET(J)
        TOTVAL(J) = TOTVAL(J) + VALUE(J)

'
'  find and store max and min value of every channel
'
        IF TIME > TVALID THEN
            IF SWCH$ = "OFF" THEN
                RMAXVAL(J) = VALUE(J)
                RMAXTIM(J) = TIME
                RMINVAL(J) = VALUE(J)
                RMINTIM(J) = TIME
            ELSE
                IF VALUE(J) > RMAXVAL(J) THEN
                    RMAXVAL(J) = VALUE(J)
                    RMAXTIM(J) = TIME
                END IF
                IF VALUE(J) < RMINVAL(J) THEN
                    RMINVAL(J) = VALUE(J)
                    RMINTIM(J) = TIME
                END IF
            END IF
        END IF
        ISIG = ISIG + 2
   NEXT J
   I = ISIG
   IF TIME > TVALID THEN SWCH$ = "ON"

'
'  eliminate unwanted time records
'
   IF NPRNT <> NCORR THEN
        NCORR = NCORR + 1
        GOTO 200
   END IF

'
'  sort thru data combine or average columns
'
   FOR J = 3 TO NWORDS
        IF CADD(J) <> 0 THEN
            FOR K = 3 TO NWORDS
                IF K <> J AND CADD(J) = CADD(K) THEN
                    VALUE(J) = VALUE(J) + VALUE(K)
                END IF
            NEXT K
```

```
        END IF
    NEXT J
'
' print columns specified and derived values
'
    PRINT #3, USING "###.#### "; TIME;
    FOR J = 3 TO NWORDS
        IF SKIP$(J) <> "YES" THEN
            PRINT #3, USING "####.#### "; VALUE(J);
        END IF
    NEXT J
    IF SCRATE$ = "YES" THEN
        PRINT #3, USING "###.#### "; ROLRAT; PCHRAT;
    END IF
    PRINT #3,
    NCORR = 1
200
    TIME = TIME + TINTERVAL
LOOP WHILE TIME < TEND

500
'
' calculate mean and varience; print out max and min
'
IF STATOP$ = "YES" THEN
   OPEN STATFIL$ FOR OUTPUT AS #6
   PRINT #6, "TIME CHANNEL STATISTICAL BREAKDOWN  - "; SDATFIL$
   PRINT #6, "Max, Min, Median, and Average:  "; SCOND$
   PRINT #6, "Time Start = "; TSTART; "  :  Time Stop = "; TEND
   PRINT #6,
   FOR I = 3 TO NWORDS
       IF SKIP$(I) <> "YES" THEN
           RMEDIAN = (RMAXVAL(I) + RMINVAL(I)) / 2
           AVERAGE = TOTVAL(I) / (TIME * DFFREQ * NPRNT)
           PRINT #6, SWNAME$(I); "  - ("; SUNIT$(I); ")"
           PRINT #6, "Maximum Value = "; RMAXVAL(I); " @ time = "; RMAXTIM(I)
           PRINT #6, "Minimum Value = "; RMINVAL(I); " @ time = "; RMINTIM(I)
           PRINT #6, "Median = "; RMEDIAN; "  :  Average = "; AVERAGE
           PRINT #6,
       END IF
   NEXT I
   CLOSE #6
END IF

'
' close files and end program
'
CLOSE #3
CLOSE #1
END
```

```
DEFSNG S
' ISIG = signal number in binary file records, starting at 1.
' IREC = byte position in binary file for start byte of the current record.
FUNCTION GETDEC (ISIG, IREC) STATIC
DIM ID AS INTEGER

GET #1, ISIG * 2 - 2 + IREC, ID                  ' signed 16 bit integer.
W = ID
IF ID < 0 THEN W = W + 65536!                    ' positive REAL in 16 bit range.
GETDEC = W / 16!                                 ' positive REAL in 12 bit range.

END FUNCTION

' ISIG = signal number in binary file records, starting at 1.
' IREC = byte position in binary file for start byte of the current record.
FUNCTION GETDOUBLEHEX (ISIG, I)
DIM ID AS INTEGER, ID1 AS INTEGER
DEFLNG I-N

ITEMP = ISIG * 2 + IREC
GET #1, ITEMP - 2, ID                            ' Signed 16 bit integer.
ID = ID AND 127
W1# = ID
ID = ID' \ 4
ID1 = ID
W1# = ID 'W1#' / 4#                              ' Positive REAL in 12 bit range.

GET #1, ITEMP, ID
ID = ID 'AND 4095
ID = ID '\ 4
W2# = ID
IF ID < 0 THEN W2# = W2# + 65536#
W2# = W2# \ 64

PRINT SIGN; ID1; ID; W1#; W2#

W2# = (W1# / 128! + W2# / 131072!) * 180!
GETDOUBLEHEX = W2#

END FUNCTION

' ISIG = signal number in binary file records, starting at 1.
' IREC = byte position in binary file for start byte of the current record.
FUNCTION GETHEX (ISIG, IREC) STATIC
DIM HB0 AS STRING * 1, HB1 AS STRING * 1, HB2 AS STRING * 1, HB3 AS STRING * 1
DIM TEMP2 AS STRING, ID AS INTEGER
SHARED FIRSTHEX$, SECONDHEX AS STRING

ITEMP = ISIG * 2 - 2 + IREC
GET #1, ITEMP + 0, HB0:  GET #1, ITEMP + 1, HB1
GET #1, ITEMP + 2, HB2:  GET #1, ITEMP + 3, HB3

ITEMP = ASC(HB0):  FIRSTLO = ITEMP
IF ITEMP = 0 THEN TEMP2 = "00" ELSE TEMP2 = HEX$(ITEMP)
IF LEN(TEMP2) = 1 THEN TEMP2 = "0" + TEMP2

ITEMP = ASC(HB1):  FIRSTHI = ITEMP
IF ITEMP = 0 THEN FIRSTHEX$ = "00" ELSE FIRSTHEX$ = HEX$(ITEMP)
IF LEN(FIRSTHEX$) = 1 THEN FIRSTHEX$ = "0" + FIRSTHEX$
```

```
FIRSTHEX$ = FIRSTHEX$ + TEMP2

ITEMP = ASC(HB2):  SECONDLO = ITEMP
IF ITEMP = 0 THEN TEMP2 = "00" ELSE TEMP2 = HEX$(ITEMP)
IF LEN(TEMP2) = 1 THEN TEMP2 = "0" + TEMP2

ITEMP = ASC(HB3):  SECONDHI = ITEMP
IF ITEMP = 0 THEN SECONDHEX = "00" ELSE SECONDHEX = HEX$(ITEMP)
IF LEN(SECONDHEX) = 1 THEN SECONDHEX = "0" + SECONDHEX
SECONDHEX = SECONDHEX + TEMP2

IW1 = (FIRSTHI * 256 + FIRSTLO) \ 64
IW1 = IW1 AND 127
W1 = IW1 'ID
IW2 = (SECONDHI * 256 + SECONDLO) \ 64
W2 = IW2

GETHEX = (W1 / 128! + W2 / 131072!) * 180!

END FUNCTION

' ISIG = signal number in binary file records, starting at 1.
' IREC = byte position in binary file for start byte of the current record.
FUNCTION GETMSDLSD (J, ISIG, IREC, SCRATE$, PCHRAT, ROLRAT, YAWRAT) STATIC
DIM ID AS INTEGER
SHARED NWPHDG, CPHDG(), NSIGS, SWNAME$(), RATE(), TINTERVAL

'
'  get msd/lsd values and apply formula
'
TEMP$ = SWNAME$(J)
ITEMP = J * 2 + IREC
GET #1, ITEMP - 2, ID                          ' Signed 16 bit integer
W1# = ID
IF ID < 0 THEN W1# = W1# + 65536#              ' Positive REAL in 16 bit range
W1# = W1# / 16#                                ' Positive REAL in 12 bit range
GET #1, ITEMP, ID
W2# = ID
IF ID < 0 THEN W2# = W2# + 65536#
W2# = W2# / 16#
W3# = (W1# * 256! + W2#) * .0054931

'
'  apply proper formula for proper channel
'

IF TEMP$ = "ROLL__(MSD)" THEN
    IF W3# > 180# AND W3# <= 360# THEN W3# = W3# - 360#
    '  calculate roll rate
    IF SCRATE$ = "YES" THEN
        IF ITEMP > 2 * NWPHDG * NSIGS THEN
            R = 0!
            FOR K = 1 TO NWPHDG
               IOFFSET = K * NSIGS * 2
               GET #1, ITEMP - 2 + IOFFSET, ID         ' signed 16 bit integer
               W1# = ID
               IF ID < 0 THEN W1# = W1# + 65536#
               W1# = W1# / 16#                         ' change to 12 bit range

               GET #1, ITEMP + IOFFSET, ID
               W2# = ID
               IF ID < 0 THEN W2# = W2# + 65536#
```

```
                W2# = W2# / 16#

                WPLUS# = (W1# * 256! + W2#) * .0054931
                IF WPLUS# > 180# AND WPLUS# <= 360# THEN WPLUS# = WPLUS# - 360#

                GET #1, ITEMP - 2 - IOFFSET, ID          ' signed 16 bit integer
                W1# = ID
                IF ID < 0 THEN W1# = W1# + 65536#
                W1# = W1# / 16#                          ' change to 12 bit range

                GET #1, ITEMP - IOFFSET, ID
                W2# = ID
                IF ID < 0 THEN W2# = W2# + 65536#
                W2# = W2# / 16#

                WMINUS# = (W1# * 256! + W2#) * .0054931
                IF WMINUS# > 180# AND WMINUS# <= 360# THEN WMINUS# = WMINUS# -
360#
                R = R + (WPLUS# - WMINUS#) * CPHDG(K)
            NEXT K
            ROLRAT = R
        END IF
    END IF
ELSEIF TEMP$ = "PITCH_(MSD)" THEN
    IF W3# > 180# AND W3# <= 360# THEN W3# = W3# - 360#
    W3# = -W3#
    '  calculate pitch rate
    IF SCRATE$ = "YES" THEN
        IF ITEMP > 2 * NWPHDG * NSIGS THEN
            R = 0!
            FOR K = 1 TO NWPHDG
                IOFFSET = K * NSIGS * 2
                GET #1, ITEMP - 2 + IOFFSET, ID          ' signed 16 bit integer
                W1# = ID
                IF ID < 0 THEN W1# = W1# + 65536#
                W1# = W1# / 16#                          ' change to 12 bit range

                GET #1, ITEMP + IOFFSET, ID
                W2# = ID
                IF ID < 0 THEN W2# = W2# + 65536#
                W2# = W2# / 16#

                WPLUS# = (W1# * 256! + W2#) * .0054931
                IF WPLUS# > 180# AND WPLUS# <= 360# THEN WPLUS# = WPLUS# - 360#

                GET #1, ITEMP - 2 - IOFFSET, ID          ' signed 16 bit integer
                W1# = ID
                IF ID < 0 THEN W1# = W1# + 65536#
                W1# = W1# / 16#                          ' change to 12 bit range

                GET #1, ITEMP - IOFFSET, ID
                W2# = ID
                IF ID < 0 THEN W2# = W2# + 65536#
                W2# = W2# / 16#

                WMINUS# = (W1# * 256! + W2#) * .0054931
                IF WMINUS# > 180# AND WMINUS# <= 360# THEN WMINUS# = WMINUS# -
360#
                R = R + (WPLUS# - WMINUS#) * CPHDG(K)
            NEXT K
            PCHRAT = -R
        END IF
```

```
        END IF
    ELSEIF TEMP$ = "P/HDG_(MSD)" THEN
        W3# = W3# - PCORRECT#
        IF SGN(W3#) = -1 THEN W3# = W3# + 360#
        '  calculate yaw rate
        IF SCRATE$ = "YES" THEN
            IF ITEMP > 2 * NWPHDG * NSIGS THEN
                R = 0!
                FOR K = 1 TO NWPHDG
                    IOFFSET = K * NSIGS * 2
                    GET #1, ITEMP - 2 + IOFFSET, ID         ' signed 16 bit integer
                    W1# = ID
                    IF ID < 0 THEN W1# = W1# + 65536#
                    W1# = W1# / 16#                         ' change to 12 bit range

                    GET #1, ITEMP + IOFFSET, ID
                    W2# = ID
                    IF ID < 0 THEN W2# = W2# + 65536#
                    W2# = W2# / 16#

                    WPLUS# = (W1# * 256! + W2#) * .0054931
                    IF SGN(WPLUS#) = -1 THEN WPLUS# = WPLUS# + 360#

                    GET #1, ITEMP - 2 - IOFFSET, ID         ' signed 16 bit integer
                    W1# = ID
                    IF ID < 0 THEN W1# = W1# + 65536#
                    W1# = W1# / 16#                         ' change to 12 bit range

                    GET #1, ITEMP - IOFFSET, ID
                    W2# = ID
                    IF ID < 0 THEN W2# = W2# + 65536#
                    W2# = W2# / 16#

                    WMINUS# = (W1# * 256! + W2#) * .0054931
                    IF SGN(WMINUS#) = -1 THEN WMINUS# = WMINUS# + 360#
                    R = R + (WPLUS# - WMINUS#) * CPHDG(K)
                NEXT K
                YAWRAT = R
            END IF
        END IF
    ELSEIF LEFT$(TEMP$, 3) = "EPR" THEN
        W3# = W3# * .008333
    ELSEIF TEMP$ = "OPT/DIST_MSD" THEN
        W3# = W1# * 16 + W2# / 256
    END IF

    W = W3#
    GETMSDLSD = W
    END FUNCTION

    ' ISIG = signal number in binary file records, starting at 1.
    ' IREC = byte position in binary file for start byte of the current record.
    FUNCTION GETREAL (ISIG, IREC) STATIC
    SHARED NWPHDG, CPHDG(), NSIGS
    DIM ID AS INTEGER

    IPOSN = ISIG * 2 + IREC
    GET #1, ISIG * 2 - 2 + IREC, ID                 ' signed 16 bit integer.
    W = ID
    IF ID < 0 THEN W = W + 65536!                   ' positive REAL in 16 bit range.
    GETREAL = W / 65536!                            ' put in range 0.0 to 1.0.
```

```
    GET #1, ISIG * 2 - 2 + IREC, ID            ' signed 16 bit integer.
    W = ID
    IF ID < 0 THEN W = W + 65536!              ' positive REAL in 16 bit range.
    W = W / 65536!                             ' put in range 0.0 to 1.0.
    GETREAL = W

  END FUNCTION

  DEFINT I-N
  SUB LPTB (MM, T, B, A1(), A2(), BZERO) STATIC
  M = MM
  ANG = 3.141593 * B * T
  FACT = SIN(ANG) / COS(ANG)
  M1 = M - M / 2
  F = 1!
  FFN = M
  SECTOR = 3.141593 / FFN
  WEDGE = SECTOR / 2!
  FOR I = 1 TO M1
    FFN = I - 1
    ANG = FFN * SECTOR + WEDGE
    AM = FACT * SIN(ANG)
    BM = FACT * COS(ANG)
    AMS = AM * AM
    DEN = (1! + BM) ^ 2 + AMS
    A1(I) = -2! * ((1! - BM * BM) - AMS) / DEN
    A2(I) = ((1! - BM) ^ 2 + AMS) / DEN
    F = F * (1! + A1(I) + A2(I)) / 4!
  NEXT I
  BZERO = F ^ (1! / M1)

  END SUB

  DEFSNG I-N
  FUNCTION RI0 (X) STATIC
  DEFINT I-N
  Y = X / 2!: T = 1E-08: E = 1!: DE = 1!
  I = 0
  DO
    I = I + 1
    DE = DE * Y / I: SDE = DE * DE: E = E + SDE
  LOOP UNTIL E * T > SDE
  RI0 = E
  END FUNCTION

  DEFLNG I-N
  SUB SETFILTERS STATIC
  SHARED NWPHDG, CPHDG()

  '
  ' calculate filter weights.
  '
  PI = 3.14159:  TWOPI = 2! * PI
  NWPHDG = 16
  FB = 2 * TSP            ' convert from Hz to range 0 to 0.5
  'ALPHA = 2.783          ' 35 dB
  ALPHA = 3.395           ' 40 dB
  'ALPHA = 5.653          ' 60 dB
  AI0 = RI0(ALPHA)
  FOR K = 1 TO NWPHDG
    AK = K
    XI0 = ALPHA * SQR(1! - (AK * AK) / (NWPHDG * NWPHDG))
```

```
  CPHDG(K) = RI0(XI0) / AI0
  OMEGA = TWOPI * AK * FB
  TEMP = 1! * (SIN(OMEGA) / AK - TWOPI * FB * COS(OMEGA)) / (AK * PI)
  CPHDG(K) = CPHDG(K) * TEMP / TSP
NEXT K
I = 0:  Y = 0!
FOR K = 1 TO NWPHDG
  Y = Y + TSP * ((I + K) - (I - K)) * CPHDG(K)  'Linear slope = TSP per step =
1
NEXT K
YSLOPE = Y
FOR I = 1 TO NWPHDG
  CPHDG(I) = CPHDG(I) / YSLOPE
NEXT I

GOTO NOCHECK
FOR I = 1 TO -NWPHDG
  PRINT I; CPHDG(I)
NEXT I

FOR IFR = 0 TO 18
  FREQ = IFR * .02
  HF = 0!
  FOR I = 1 TO NWPHDG
    AI = I
    HF = 2! * CPHDG(I) * SIN(TWOPI * AI * FREQ) + HF
  NEXT I
  PRINT USING "###.#### "; FREQ / TSP; HF / TWOPI
NEXT IFR

PRINT TSP
FOR I = 0 TO 1
  Y = 0!
  FOR K = 1 TO NWPHDG
    Y = Y + TSP * ((I + K) - (I - K)) * CPHDG(K)'Linear slope = TSP per step =
1
  NEXT K
  PRINT I; Y; YSLOPE
NEXT I
END
NOCHECK:

END SUB

SUB SETTANFILT STATIC
DIM AL1(100), AL2(100), BL0(100), BL1(100), BL2(100), HF(100)
DIM MM AS INTEGER
SHARED B01, B02, A11, A12, A21, A22, TANFILTFREQ

TWOPI = 6.2831853#: PI = TWOPI / 2!
MM = 4
FB = TANFILTFREQ
' PRINT TSP

' High pass section.
CALL LPTB(MM, TSP, FB, AL1(), AL2(), BZERO)
FOR I = 1 TO MM / 2
  BL0(I) = 1! * BZERO:  BL1(I) = 2! * BZERO:  BL2(I) = 1! * BZERO
'  PRINT USING "###.##### "; AL1(I); AL2(I); BL0(I); BL1(I); BL2(I)
NEXT I
```

```
B01 = BL0(1):  B02 = BL0(2)
A11 = AL1(1):  A12 = AL1(2):  A21 = AL2(1):  A22 = AL2(2)

GOTO SKIPCHECK
FOR I = 1 TO 15
  FREQ = I * 2
  CALL TTRAN(AL1(), AL2(), BL0(), BL1(), BL2(), MM, TSP, FREQ, ABZ, PHS)
  PRINT USING "##.##  ###.#####  "; FREQ; ABZ
  HF(I) = ABZ
NEXT I
END
SKIPCHECK:

END SUB

SUB TAN2FILT (W, J) STATIC
DIM WM1(80), WM2(80), Y1M1(80), Y1M2(80), Y2M1(80), Y2M2(80)
SHARED B01, B02, A11, A12, A21, A22

Y1 = B01 * (W + 2! * WM1(J) + WM2(J)) - A11 * Y1M1(J) - A21 * Y1M2(J)
Y2 = B02 * (Y1 + 2! * Y1M1(J) + Y1M2(J)) - A12 * Y2M1(J) - A22 * Y2M2(J)
Y1M2(J) = Y1M1(J):  Y1M1(J) = Y1
Y2M2(J) = Y2M1(J):  Y2M1(J) = Y2
WM2(J) = WM1(J):  WM1(J) = W
W = Y2

END SUB

DEFINT I-N
  SUB TTRAN (A1(), A2(), B0(), B1(), B2(), M, T, FREQ, ABZ, PHS) STATIC

FACT = 6.283185 * T
IP = M - M / 2
ADD = 0!
PREV = 0!
FD = FREQ * FACT
S1 = SIN(FD)
C1 = COS(FD)
A = 2! * FD
S2 = SIN(A)
C2 = COS(A)
ABSA = 1!
PHSA = 0!
FOR J = 1 TO IP
  AR = B0(J) + B1(J) * C1 + B2(J) * C2
  AI = -B1(J) * S1 - B2(J) * S2
  ANM = AR * AR + AI * AI
  PND = 0!
  IF AI <> 0! OR AR <> 0! THEN PND = ATN(AI / AR)
  AR = 1! + A1(J) * C1 + A2(J) * C2
  AI = -A1(J) * S1 - A2(J) * S2
  ABSA = ABSA * ANM / (AR * AR + AI * AI)
NEXT J
ABZ = SQR(ABSA)

END SUB
```

APPENDIX E
Axle Differential Load Analysis

Figure E1 is a diagram of a landing gear under loading due to lateral motion. Intuitively, this motion causing a net side force on the landing gear will also cause a moment about the landing gear axle, causing axle differential load. Axle differential load is defined by the following as illustrated in figure E1.

$$ADL = F_{VSr} - F_{VSl} \qquad \text{(E1)}$$

In this equation ADL is axle differential load.

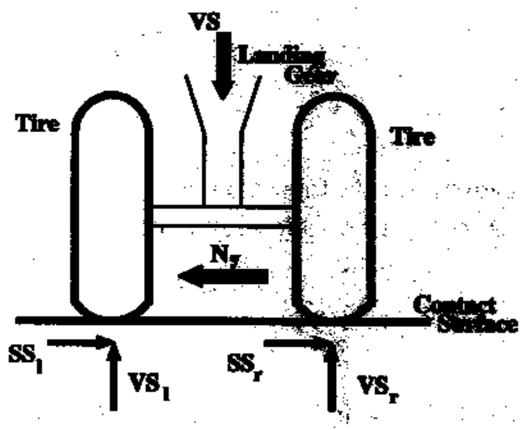


FIGURE E1: LANDING GEAR UNDER LATERAL LOADING

From the load diagram given as figure E2 it is obvious that the total side shear on the landing gear is equal to the sum of the side force reaction forces as given below.

$$F_{SS} = F_{SSl} + F_{SSr} \qquad \text{(E2)}$$

Side force is manifested by lateral acceleration N_y as related by the following equation.

$$F_{SS} = N_y\, W_{AC} \qquad \text{(E3)}$$

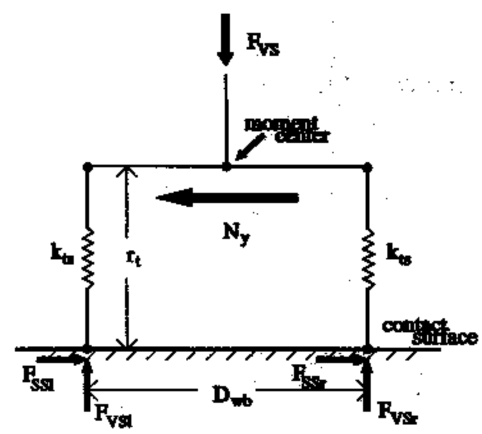


FIGURE E2: LOAD DIAGRAM OF LANDING GEAR

By summation of moments about the labeled moment center the following equation can be obtained.

$$0 = \frac{F_{VSr} D_{WB}}{2} + F_{SSr}\, r_t + F_{SSl}\, r_t - \frac{F_{VSl} D_{WB}}{2} \qquad \text{(E4)}$$

In the above equation r_t is the loaded radius of the tire and D_{WB} is the wheel base distance or contact patch distance. Collecting side forces and vertical forces the following manipulations can be performed.

$$\frac{F_{VSl}D_{WB}}{2} - \frac{F_{VSr}D_{WB}}{2} = F_{SSr}\,r_t + F_{SSl}\,r_t \tag{E5}$$

$$\frac{D_{WB}}{2}(F_{VSl} - F_{VSr}) = r_t(F_{SSr} + F_{SSl}) \tag{E6}$$

We can substitute total side shear and axle differential load as defined above and solve for F_{ADL} to obtain the following equation.

$$F_{ADL} = \frac{2r_t\,F_{SS}}{D_{WB}} \tag{E7}$$

For the B-727 r_t is 21.5 inches and D_{WB} = 36 inches. This gives the following relation.

$$F_{ADL} = 1.2\ F_{SS} \tag{E8}$$

Measurements show that:

$$F_{ADL} \approx F_{SS} \tag{E9}$$